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OF THE

# New England Water Works

# ASSOCIATION.

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OF THE

# New England Water Works ASSOCIATION.

1894-95.

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# NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. IX. September, 1894. No. 1.



*This Association, as a Body, is not responsible for the statements or opinions of any of its members.*


## PROCEEDINGS OF THE THIRTEENTH ANNUAL CONVENTION.

BOSTON, MASS., June 14, 15 and 16, 1894.

The sessions of the Thirteenth Annual Convention of the Association were held at the United States Hotel, Boston, on Thursday forenoon, afternoon and evening, June 14th, and on Friday forenoon and evening, June 15th. Ample provision was made in the United States Hotel for the exhibit of water works appliances, and there was a fine display, this feature of the meeting being in charge of Mr. Harold L. Bond. The attendance at the convention was unusually large.

### FORENOON SESSION.

THURSDAY, June 14, 1894.

The convention met at 10.30 A. M., George E. Batchelder, of Worcester, President, in the chair. The Hon. Nathan Matthews, Jr., Mayor of the city of Boston, was presented and he spoke as follows:

### ADDRESS OF WELCOME BY MAYOR MATTHEWS.

*Mr. President and Gentlemen of the New England Water Works Association:* It gives me pleasure to welcome you to this city. I trust your visit will be pleasant and profitable, and, speaking for the city authorities, I will say on their behalf that nothing will be left undone by them to make it so.

A large part of the business of your conventions, I have noticed, is devoted to valuable discussions of the different sanitary and scientific problems connected with the procurement of a sufficient water supply for our great cities. I notice, however, that these discussions are confined to the sanitary and scientific problems, and do not seem to take into account another aspect of this great question of municipal water supply which is equally important, in fact which lies at the bottom of the whole question, and that is the financial aspect.

I had occasion some two years ago to make some inquiry into the operation of the different municipal water plants in Massachusetts, and I could find nothing in print upon the subject, relating to the financial operation of those plants. I have been unable to find anything relating to municipal water works in foreign countries, either, that is, I have been unable to lay my hands upon any comprehensive treatise of the financial results attendant upon the municipal ownership of water works.

Now it seems to me, Mr. President and gentlemen, that there is no public question which invites and demands consideration more than this, and that there is none which will better pay the members of this Association to devote their time to. The field is free and open, practically nothing has been written on the subject, and yet it is one of the most important questions that a municipal administration has to face.

In theory, of course, in the contemplation of our State constitution and of our statute laws—(I am speaking of the Commonwealth of Massachusetts now rather than of the other New England States, but what I say about Massachusettes laws applies, I think, in the main to those of the other New England States)—a municipal water works is supposed to run itself; it is supposed to be self-supporting. That is to say, the annual rates, the receipts from the sales of water, are expected in the first place to pay the annual cost of maintenance; in the second place to pay for the cost of all those extensions and improvements which in a properly conducted private corporation would be paid for out of the earnings rather than capitalized; and, in the third place, to yield a sum sufficient to keep down the interest and in time to pay off the principal of all loans incurred for the purpose of establishing the plant. It never was contemplated that a debt for water purposes should be perpetual in duration, much less that that debt should be constantly upon the increase. And, furthermore, in theory at least, the general taxpayers, the community at large, do not expect to be called upon to make good any deficiency in the finances of the water department.

In other words, our water works are supposed to be self-supporting. And yet, gentlemen, it is my opinion that not one in ten of the municipal water works of Massachusetts is self-supporting, not one in ten.

Now, that is a very serious thing. Municipal ownership is on trial. The case of water is the most favorable case for municipal ownership that can possibly be made out. It is the one to which municipal ownership is most adapted, and is conceeded by all, because there are certain improvements of a strictly sanitary character which a municipality can well afford to undertake, and must in its own protection undertake, no matter what the cost, which a private corporation, organized solely for the profit of its stockholders, could not be expected to pay for. So that in the case of water you have the ideal case for municipal ownership; you have that kind of a natural monopoly, which is best situated to be worked and managed under public control.

But everybody assumes in asking for public control over our water works that they can be made self-supporting. I question very much whether they generally are self-supporting.

Of course we all know the difficulty in making a public water plant self-supporting. We know, of course, the competition that exists between the different cities of this country for manufactures, and we know to what a great extent the cost of water enters into the ability of a community to compete for manufactures with its neighbors. Here in the city of Boston we have a most unfortunate illustration of the difficulty of competition due to the excessive cost of water. Boston is obliged to compete for instance with Philadelphia and Baltimore in manufactures, and both of those cities have great and practically limitless sources of water at their very door; whereas the metropolis of New England has no natural source of water supply, and what we have today has been manufactured, has been almost literally created out of nothing, by means of storage basins. Of course that means a great expense for interest and sinking fund requirements; and therefore, the rates for water in this community are naturally and necessarily very much higher than in Baltimore or Philadelphia. This cannot be helped, it is inevitable, but it creates a pressure upon the municipal authorities to reduce the rates in the interest of the local manufacturers, below the point of profit. That is one source of trouble.

Another cause which I have found to operate in this city, and I believe it to be equally potent in other communities that manage their own water works, is the assumed popularity to be got for the administration for the time being by reducing rates. The financial consequences of reducing rates below the point of profit are not seen that year; they are not felt till the next year. They are shouldered by the next administration, and not by that for the year in question. And I think there have been deliberate attempts in various cities of the commonwealth to reduce rates below the point of profit, so that the water works have ceased to be self-supporting, for the mere purpose of deriving some temporary popularity for the administration that happens to be in power.

There are those two great causes constantly pressing upon the municipal administration to reduce rates below the point at which the municipal water works can be supported, without drawing either upon the general tax levy, or swelling the debt beyond its proper limit.

One result of these causes has been, so far as I have been able to investigate the problem, is this: that in many cases our water works are managed at an actual loss even for current expenses, without taking any account of the debt requirements, and that loss is made good by general taxation.

Now, that may be a justifiable policy, but it is not the theory upon which municipalities have been authorized by the laws of Massachusetts to undertake the task of supplying their inhabitants with water. The theory always has been that the works should be self supporting, that the water-takers should pay the entire annual cost, and that no part of that cost should be distributed among the taxpayers, among the community at large. But I think that in very many cities you will find upon examination that the general taxpayers are obliged to contribute towards the maintenance of the water works. That, however, as I have said, may, perhaps, be justifiable on general principles of

municipal economy, although I do not think it is within the theory of our water legislation.

But there is another and a far more evil consequence of loose financeering respecting water works, which is also quite common, so far as my investigations go, and that is the expansion of the municipal debt for purposes which should never have been covered by the issue of bonds.

I believe that a great majority of the municipal water plants of Massachusetts are in the condition of some of our railroads, steam and street railroads both, enormously over-capitalized. The community has not been satisfied with borrowing simply the money needed for the original plant, or for works of great construction, such as receiving basins and the like, which a private corporation would not hesitate to capitalize and pay for by the issue of stock or bonds. The community has not been satisfied with that, but it has gone further in altogether too many cases. It has capitalized the cost of annual extensions, ordinary pipe laying, and sometimes, I fear, it has even capitalized current expenses of maintenance. But the great wrong that has been done to the municipalities of this commonwealth in the maladministration of their water works has been, in my opinion, the capitalization by borrowing money, of items of annual expenditure. Any private corporation, gas, electric light, water or what not, which should capitalize annually the cost of extensions, which are an ordinaary annual expenditure, would soon necessarily find itself unable to pay dividends, or, perhaps, unable to meet its obligations.

There is very little material to be got relating to water companies, but the subject has been very exhaustively treated in so far as it effects gas companies, and there the question, you can see at once, is exactly the same. If a gas company, properly managed, must pay for annual extensions out of annual receipts and not capitalize them, it is obvious that a water company must do the like, and it is further obvious, gentlemen, that a municipal corporation must do the like also. But how many of them, I ask, are there in Massachusetts, who have done that, who have paid for their annual extensions out of their annual receipts? How many of them, on the contrary, have issued bonds payable in ten, twenty or thirty years for ordinary annual extensions?

Now, what is the result of this policy? In a private corporation it would be insolvency. In a municipal corporation it is an indefinite annual extension of debt which some time or other must become apparent, and will then be not only an apparent, but a real and very serious burden upon the community. It is easy enough to conceal it for the first few years, in fact for quite a number of years, but in the end an indefinite extension of the debt for purposes the cost of which ought to have been defrayed out of the annual receipts, is sure to result in the accumulation of an indebtedness, the interest and sinking fund requirements upon which will be heavily felt in the annual tax levy.

I have brought this matter to your attention today because it seems to me that the people of this country are looking with great interest to all discussion, pertinent and valuable, relating to the great question of the public ownership of these natural monopolies. In Massachusetts the question has practically been decided in favor of municipal ownership of water plants.

And yet, if that ownership is not managed wisely, if municipal control of our water supplies is not managed conservatively, as a private corporation would manage its affairs, there is bound sooner or later to come financial trouble which will bring the whole system of municipal ownership into disrepute. And what I urge upon you, as an organization representing the interests of municipal water plants in this community, is to investigate this subject, to find out just exactly what the financial results of the municipal water works in the different towns and cities of New England are; which of them are managed conservatively from a business and financial standpoint, and which of them are not, and then to devise if you can, a remedy for those which are being mismanaged. I would throw out as the one suggestion which I have to make to you, as the result of some years of attention to our local water problem, the importance of confining the issue of bonds to defray the cost of large constructions, and of making the rates sufficiently high to cover besides the debt requirements, not only the cost of maintenance but also the cost of all those extensions and other items of expenditure which are annual in their character, necessarily recurring from year to year, and which in the case of a private corporation would ordinarily be defrayed from income.

Gentlemen, I have thought this matter of sufficient importance to bring it to your attention this morning, because I did not know of a more influential or intelligent body of men to make the suggestion to. I only hope something will come of it, and that before another year has passed we shall have some authoritative and thorough examination into this matter and a valuable printed report thereon.

And now, Mr. President and gentlemen, I can simply repeat what I said at the beginning, that I am very glad to see you all here today, and that it gives me great pleasure to welcome you to the city. I hope your stay here will be pleasant, and, so far as the water board and myself can make your visit a happy one, we will endeavor to do so.

The President. Gentlemen, it must be apparent to every one who has heard the remarks of His Honor the Mayor, that he has been a close student in water works matters. He has certainly given us important suggestions which it will be well for this convention to consider, and I trust they will be given attention, and that good results will follow. Mr. Mayor, I thank you in behalf of the New England Water Works Association for your courtesy in being with us this morning.

The convention then proceeded to the regular order of business.

On motion of the Secretary the reading of the records of the last meeting was dispensed with.

The executive committee not being ready to report upon applications for membership, the President addressed the convention.

## ANNUAL ADDRESS OF PRESIDENT BATCHELDER.

*Gentlemen of the New England Water Works Association:* We meet today, for the thirteenth time in annual convention and I congratulate you on the large attendance and the excellent prospect for a successful convention. Since our last annual meeting in Worcester, we have held five meetings. The first of these was a field day at Plymouth, in September. Although I was unable to be present I am informed by those who were fortunate in being there, that a most enjoyable outing was had. Much credit for the delightful time enjoyed by the members and their ladies was due to the committee of arrangements, consisting of Secretary Coggeshall and Mr. A. S. Glover. The other four meetings were held in Boston, one at the Parker House, the other three at Young's Hotel, meetings were held in December, January, February and March. The average attendance was about one hundred, showing the increasing interest of the members and friends of our society.

The special papers which have been presented have been of the highest order; the discussions following the papers have been instructive and of much benefit to the society.

We are to be congratulated on the acquisition of so many valuable members during the past year. Every member of this Association should endeavor to induce officials of the different New England water works to become members. I do not see how any official connected with water works, no matter what his position may be, or how small a plant he is connected with, can afford to get along without being an active member of this Association. By our frequent meetings we become acquainted with each other and by an interchange of ideas a fund of information is gathered, which is beneficial to all. The information contained in any single number of the JOURNAL more than repays for the slight annual dues required by the Association.

Several of my predecessors have called your attention to the necessity of having the JOURNALS bound. I will again call your attention to this necessity, if you desire to preserve in convenient form valuable information relating to water works.

Our membership is now 443; our treasury is on a solid financial basis. The details of our year's work will be presented in the reports of the Secretary and Treasurer, to which I especially call your attention.

I desire to call the attention of the Association to a bill introduced in the Massachusetts legislature during the past winter in relation to the appointment of a State Inspector of Meters. The bill, as drawn, practically removed from local officials all control of the meter system, placing the same in the hands of a State Inspector with headquarters in Boston. When the bill was before the committee, individual members of this Association appeared in opposition and as a report granting the petitioners leave to withdraw was presented to the legislature it is presumed that the facts presented to the committee why the bill should not become a law, had much weight. As it must be apparent to any one conversant with the matter, that a selfish motive was behind the bill, it is just as plain that a new or amended bill will

be presented to the next legislature for the purpose of accomplishing the same selfish ends. Should this prove true I trust that all water works officials will examine the bill carefully, and if in their judgment it is found to be detrimental to the interests of water departments, that every honorable effort will be used against it becoming a law. It may seem a little out of place to bring this matter of a Massachusetts bill before this convention, which represents all New England, but the time is not far distant when a similar bill will be introduced in the legislative bodies of New England.

At this time I desire to call your attention to the advisability of having all water works using meters have a modern and complete plant for the purpose of testing all meters, and that as far as possible the same method be adopted by all water works, and recommend that a committee be appointed at the meeting who will investigate and report at some future time, the best, most accurate and simple method of testing meters.

Representing as most of us do water works owned by cities and towns, we stand between the consumer and the town or city, and it is our duty to see that the consumer receives exact justice at our hands.

Many members have expressed a desire for a field excursion in September to the White Mountains. If this desire is shared by a large number of the members some action should be taken at this meeting.

Death has been busy in our ranks during the past year, and it becomes my sad duty to report the loss of thirteen of our members since our annual convention.

Sherman E. Grannis, of New Haven, who died August 10, 1893, was one of the Vice Presidents for the years ending 1884 and 1886, and filled that office at the date of his death. He joined the Association at the date of its organization, June 20, 1883.

Charles R. Dyer, Portland, Maine, who died September 12, 1893, was one of the Vice Presidents for the year ending June, 1892.

William Dixon, formerly Superintendent at Mt. Pleasant, died September 23, 1893.

C.W. S. Seymore, Superintendent at Hingham, Mass.. died October 16, 1893.

Dr. C. F. Crehore, Superintendent of Newton Water Board, died November 7, 1893.

Robert K. Martin, Chief Engineer of Baltimore, Md., Water Works, died November 24, 1893.

E. P. Le Baron, Chairman of Water Board of Middleboro, died December 1, 1893.

T. H. McLaughlin, Superintendent Texarkana, Ark., died December 17, 1893.

C. N. Brainard, Treasurer Water Works Skowhegan, Me., died December 25, 1893.

W. D. Taylor, Superintendent of Dover, N. H., died January 2, 1894.

Weaver Osborn, formerly of Water Board, Fall River, died February 3, 1894.

Hiram Nevons, Superintendent Water Works Cambridge, Mass., died May 27, 1894 ; was Vice President for year ending June, 1883; President for the year

ending June, 1889; Treasurer from June, 1889, to day of his death; joined the Association at date of its organization.

Gilbert Murdoch, Chief Engineer of Water and Sewer department, St. Johns, N. B., died May 28, 1894.

Most of the members removed by death were old and active members of the Association. Brother Nevons was probably the best known to you all. He had filled at different times the important offices in the Association. He always took a lively interest in the society, and was present at nearly all the meetings. He was possessed of those sterling qualities which we all so much admire. "To know him was to respect him."

In conclusion, I desire to thank all who have so ably assisted me in making every meeting of this Association one of interest, and especially do I desire to thank Secretary Coggeshall for the hearty co-operation and courtesy which he showed during the past year.

Our Association is a strong and harmonious body, no petty jealousy has crept in to destroy our usefulness, and I trust that in the future we may be as free from it as we have been in the past. Under these favorable conditions our Association is capable of doing lasting good for its members as well as for the people whom they represent.

The Secretary submitted the following:

## ANNUAL REPORT OF THE SECRETARY.

NEW ENGLAND WATER WORKS ASSOCIATION,
OFFICE OF THE SECRETARY,
NEW BEDFORD, MASS., June 11, 1894.

TO THE MEMBERS OF THE NEW ENGLAND WATER WORKS ASSOCIATION:

*Gentlemen*: Your Secretary herewith presents his annual report.

On June 1, 1893, the membership of this Association was as follows, viz:

| | |
|---|---|
| Active members | 338 |
| Honorary members | 5 |
| Associate members | 69 |
| Total | 412 |

During the year there has been a loss of thirty-seven members, from the following stated causes:

| | |
|---|---|
| Resignations | 16 |
| Deceased | 14 |
| Suspended for non-payment of dues | 7 |
| | 37 |

Sixty-eight applications for membership have been presented, endorsed by the executive committee, all of which have received favorable action.

The membership at this date is

| | |
|---|---|
| Active members | 365 |
| Honorary members | 5 |
| Associate members | 73 |
| Total | 443 |

The net gain for the year has been 31 members.

It is with feelings of profound sorrow that your Secretary has been obliged to record the death of our late Treasurer Hiram Nevons, Esq., which occurred on May 27, 1894.

From a long official, as well as personal acquaintance with Mr. Nevons, your Secretary would bear witness to the fact that he was in every way worthy of all the trusts which were reposed in him.

"Tell the boys that I would like to see them all once more" was his last message to you, said to the writer, as he clasped his hand in bidding him farewell as he lay upon his bed a few days before his death.

In order that the work of the Association might not be disturbed your Secretary was authorized by the members of the executive committee to pay all outstanding claims, from moneys in his possession and present a report of his financial operations to the Association.

Your Secretary has endeavored to pick up the threads of the work of our late Treasurer and will now present an account of the same to you in connection with his own report.

And first your Secretary would submit a report of his own financial doings.

R. C. P. Coggeshall, Secretary, in Account with the New England Water Works Association.

Receipts.

Five hundred and ninety collections have been made which may thus be itemized:

| | |
|---|---|
| Advertisements | $ 1,735 00 |
| Initiations | 343 00 |
| Dues | 1,347 00 |
| Sale of Journals | 219 25 |
| Sale of Badges | 10 65 |
| | $3,654.90 |

Expenditures.

| | | | |
|---|---|---|---|
| 1893. | | | |
| July 26 | Paid | Hiram Nevons, Treasurer | $ 800 00 |
| Dec. 5 | " | Hiram Nevons, Treasurer | 1,200 00 |
| 1894. | | | |
| May 17 | " | Bacon & Burpee | 71 00 |
| May " | " | Electro Light Engraving Co | 12 25 |
| June 7 | " | The Day Publishing Co | 244 28 |
| " " | " | R. C. P. Coggeshall (salary) | 250 00 |
| " " | " | R. C. P. Coggeshall (incidentals) | 112 36 |
| " " | " | W. H. Richards (salary and incidentals) | 97 21 |
| " " | " | Mercury Publishing Co | 179 55 |
| " " | " | Walter T. Almy | 23 20 |
| " 11 | " | Balance on hand in Citizens National Bank, New Bedford, Mass | 665 05 |
| | | | $3,654 90 |

Your Secretary would also submit the following statement drawn from the books of your late Treasurer, Hiram Nevons, Esq.

HIRAM NEVONS, TREASURER, IN ACCOUNT WITH THE NEW ENGLAND WATER WORKS ASSOCIATION:

RECEIPTS.

| | | |
|---|---|---|
| 1893. | | |
| June 14 | Balance on hand as per last report | $ 2,913 67 |
| " 20 | Received from National City Bank note dated June 20,'93 | 500 00 |
| July 27 | Received from R. C. P. Coggeshall, Secretary | 800 00 |
| Dec. 6 | Received from R. C. P. Coggeshall, Secretary | 1,200 00 |
| 1894. | | |
| Jan. 17 | Cambridgeport Savings Bank, Interest since last report | 30 22 |
| Mar. 30 | Cambridge Savings Bank, Interest since last report | 13 58 |
| | | $4,557 47 |

EXPENDITURES.

| | | |
|---|---|---|
| 1893. | | |
| June 20 | Paid Morris Knowles | $2 65 |
| " " | " Charles H. Baldwin | 16 94 |
| " " | " Electro Light Engraving Co. | 271 00 |
| " " | " W. H. Richards | 107 08 |
| " " | " Day Publishing Co | 333 66 |
| " 23 | " T. P. Taylor | 29 00 |
| June 26 | " F. W. Wright | 53 88 |
| July 12 | " Bacon & Burpee | 40 00 |
| July 27 | " Rockwell & Churchill | 82 15 |
| July 27 | " F. W. Dean | 15 10 |
| Aug. 16 | " Rockwell & Churchill | 74 30 |
| " " | " " " | 44 65 |
| Sept. 22 | " W. H. Richards | 102 31 |
| " 27 | " Day Publishing Co | 128 45 |
| Oct. 25 | " Rockwell & Churchill | 4 50 |
| Dec. 16 | " Mercury Publishing Co | 231 14 |
| " " | " W. H. Richards | 85 15 |
| " " | " Parker House | 15 00 |
| Dec. 16 | " R. C. P. Coggeshall | 250 00 |
| " " | " R. C. P. Coggeshall | 152 08 |
| " " | " Engineering News Publishing Co. | 1 93 |
| " " | " Electro Light Engraving Co. | 11 83 |
| " " | " Dexter Brackett | 10 95 |
| " " | " Technology Quarterly | 11 00 |
| | *Carried forward,* | $2,074 75 |

| | | | |
|---|---|---|---|
| | *Brought forward,* | | $2,074 75 |
| 1894. | | | |
| Jan. 31 | Paid J. R. Whipple & Co | | 15 00 |
| " " " | Day Publishing Co | | 249 47 |
| Feb. 7 | " Engineering News Publishing Co | | 2 00 |
| " " " | Electro Light Engraving Co | | 2 93 |
| Feb. 20 | " Dean & Main | | 6 80 |
| " " " | Electro Light Engraving Co | | 4 91 |
| " " " | Photo Elec. Light Man'f'g Co | | 3 50 |
| " " " | Engineering Record | | 2 75 |
| " " " | J. R. Whipple & Co | | 15 00 |
| Mar. 19 | " Lettice R. Washburn | | 17 08 |
| " " " | J. R. Whipple & Co | | 24 00 |
| " " " | Sisson & Ring | | 3 43 |
| " " " | W. H. Richards | | 105 28 |
| Mar. 21 | " Day Publishing Co | | 202 05 |
| " 30 | " National City Bank, paid note bearing date June 20, '94 | | 500 00 |
| 1893. | | | |
| Oct. 1 | " National City Bank, interest on note | | 8 42 |
| 1894. | | | |
| Mar. 30 | " " " " " " | | 15 00 |
| April 24 | " Engineering Record | | 6 70 |
| 1894. | | | |
| June 1 | Balance on hand | | |
| | National City Bank | $79 56 | |
| | Cambridge Savings Bank | 28 48 | |
| | Cambridgeport Savings Bank | 1,190 36 | |
| | | | 1,298 40 |
| | | | $4,557.47 |

Summary of Financial Statements of Secretary and Treasurer :

| | |
|---|---|
| Balance on hand as per Treasurer's statement | $1,298 40 |
| " " " Secretary's " | 665 05 |
| Total available balance, June 11, 1894 | $1,963 45 |
| Balance June 14, 1893 | $2,013 67 |
| " " 11, 1894 | 1,963 45 |
| The expenditures of the year have exceeded the receipts | $50 22 |

Respectfully submitted,

R. C. P. COGGESHALL, *Secretary.*

We have examined the above account and approve it as correct.

J. C. WHITNEY,
JOHN L. HARRINGTON, } *Finance Committee.*

I would say, Mr. President, in connection with this report, that last year there were three bills aggregating $443.39 which were sent to the Treasurer in time for his last annual report, but by some delay in the mail they failed to reach

him until a week after the convention, so he was able, by not having those bills to pay, to make a favorable report. Had those bills been paid, there would have been a deficit of about $350. Your Executive Committee, becoming aware of that fact, have worked to eliminate that deficit in addition to meeting the regular expenditures of this year. There is now due the Association about $43 for dues, and about $60 for advertisements, and if all money due the Association had been collected before this statement was prepared, the report would have shown that we had overcome the deficit of last year, paid all bills, and a balance left besides. Under the circumstances, I think the Executive Committee have done very well. (Applause.)

On motion of Mr. Cook the reports of the Secretary, for himself and for the Treasurer, were accepted and placed on file.

On motion of Mr. Hall, seconded by Mr. Holden it was, voted that a committee of five be appointed by the President to nominate a list of officers for the ensuing year, and later, the President appointed the following named gentlemen as the nominating committee: Messrs Hall of Quincy, Noyes of Newton, Holden of Nashua, N. H., Kieran of Fall River, Crandall of Burlington, Vt.

THE PRESIDENT. I expected the Mayor of Worcester would be with us today, but he has been unexpectedly detained, and I will ask the Secretary to read a letter which I have received.

MAYOR'S OFFICE,

WORCESTER, MASS., June 12, 1894.

GEO. E. BATCHELDER, ESQ., President New England Water Works Association:

Dear Sir—Your kind invitation to be present on the occasion of the Thirteenth Annual Convention of your Association is duly received.

I very much regret that owing to a great pressure of official duties this week I shall be unable to attend. The papers which are to be read seem to me, to be on topics of particular interest, and the discussion of them cannot fail to be of profit to the members. Associations like yours should have the good will and support of all who are interested in the consideration of such important questions as naturally engage your attention.

Wishing you a most successful convention, and grateful for the honor shown Worcester in having you as the President of the Association during the past year, I subscribe myself, Yours truly,

HENRY A. MARSH.

MR. BILLINGS. Mr. President, I listened with great interest to the address of the Mayor of Boston in relation to the financial questions involved in the management of Water departments, and I listened with especial interest because some years ago, in connection with our Secretary, I had the pleasure of assisting in the preparation of the statistics of the New England Water Works and of Water Works throughout the country. Those statistics would furnish to some extent the material needed in the investigation suggested by His Honor the Mayor of Boston. His suggestion seems to me so pertinent and so valuable

that I would move that a committee be appointed to take the matter into consideration and report upon it at some future time. There is no necessity for haste about it, and I think the committee might well be given a year in which to make their investigations and prepare their report, but notice of the Mayor's remarks I think should be taken. I would suggest that the committee consist of three, and be appointed by the chair.

The motion was adopted, and subsequently the President appointed as the committee, William R. Billings, John R. Freeman and Freeman C. Coffin.

The special committee continued at the the last convention to consider the recommendations made by ex-President Noyes at the Hartford convention in regard to permanent headquarters, were given further time in which to report.

The first paper upon the programme was then read by George F. Chace, Superintendent, Taunton, Mass., the subject being, "Laying a 16-inch Main Across a Rocky Mill Stream and Over a Dam."

The Secretary read extracts from a paper by William Paul Gerhard, Civil and Sanitary engineer, New York City, on "The Water Service and Fire Protection of Theatres," after which the convention adjourned until afternoon.

## AFTERNOON SESSION.

At the opening of the afternoon session the Secretary read a communication from Samuel Little, President of the West End Street Railway Co., inviting the members to visit the Albany Street power station of the road.

The Secretary read the names of the following applicants for membership, recommended by the Executive Committee:

### MEMBERS ELECTED THURSDAY, JUNE 14, 1894.

#### RESIDENT ACTIVE MEMBERSHIP.

Harrison P. Eddy, Superintendent Sewer Department, Worcester, Mass.; John W. D. Fifield, Member Board of Water Commissioners, North Brookfield, Mass; Julius C. Gilbert, Superintendent Water Works, Whitman, Mass.; T. G. Hazard, Jr., Civil Engineer, Narragansett Pier, R. I.; William B. Hawes, Water Commissioner, Fall River, Mass.; Frederick A. McClure, City Engineer, Worcester, Mass.; Asa M. Mattice, Mechanical Engineer, Cambridge, Mass.; William S. McNary, Member Water Board, Boston, Mass.; James L. Rice, Superintendent Water Works, Claremont, N. H.; H. O. Smith, Water Commissioner, Leicester, Mass.; Edwin W. Snow, Superintendent Water Works, Orange, Mass.; A. R. Wadsworth, Civil Engineer, Farmington, Conn.; James H. Stanwood, Instructor Mass. Inst. of Technology, Boston, Mass.

#### NON-RESIDENT ACTIVE.

Ludovic de la Vallee Poussin, Civil Engineer, Montreal, Canada.; E. W. King, Secretary and Treasurer Water Works, Great Falls, Montana; James E. Tryon, Water Supply Engineer of the Fire Commission, Detroit, Mich.; John S. Warde, Superintendent Staten Island Water Co., West New Brighton, Staten Island, N. Y.; T. D. Miller, Secretary Water Works, Norwich, N. Y.

ASSOCIATE MEMBERS.

Eagle Oil and Supply Co., Clarence N. Goward, President, Boston, Mass.; Fuel Gas and Manufacturing Co., Pittsburg, Pa.; The General Manufacturing Co., Louis A. Pollard, Treasurer, Brooklyn. N. Y.; Metropolitan Meter Co., Boston, Mass.; New York Filter Co., W. M. Deutsch, Manager, New York City; Alexander E. Schnee, Pohle Air Lift Pump, New York City; The Star Pipe Jointer Co., William G. Spear, General Manager, Quincy, Mass.

On motion of Mr. Chace the Secretary was authorized to cast one ballot for the Association in favor of the applicants, which he did, and they were declared elected.

Mr. J. J. R. Croes, Civil Engineer, New York City, who was to have contibuted a paper on "Some Examples of Underground Water Supply," sent the following letter, which was read by the Secretary :

NEW YORK, June 13th, 1894.

R. C. P. COGGESHALL, ESQ., Secretary New England Water Works Association :

Dear Sir—I had the paper which I promised for the Boston meeting of the Association on "Some Examples of Underground Water Supply" well in hand, when I was suddenly called upon to go to South Dakota to investigate an extensive proposition for the distribution of water over the surface of the ground, so that I had to drop my consideration of subterranean supplies and look at water only in a superficial manner.

My stay at Rapid City was protracted to such a length and the study of the subjects which were brought to my attention while there has occupied my time so much since that I have been unable to complete the paper which I promised you.

I find it impossible to attend the meeting, greatly to my regret.

I must ask you, therefore, to make my apology to the Association for this apparent discourtesy and to say that the object I had in view in the preparation of the paper, was to show that an underground source of supply of water for towns is generally limited in its capacity and that the quantity which can be obtained decreases continually from year to year.

Examples of Princeton, N. J., Prospect Park, Brooklyn, N. Y., Indianapolis, Ind., etc., were to be cited by me among others in confirmation of my views, and records of experiments in pumping from tubular wells at Newark, Syracuse and other places, given somewhat in detail, in corroboration of the opinions expressed.

I wish that you would call the attention of the meeting to this subject and would request such members as have had experience with the operation of water supplies drawn from subterranean sources, to the fact that I should be pleased to receive from all of them details, of the depth of the surface of the ground water, below the surface of the ground at the beginning of operations and the effect upon the surface of the subterranean water produced by a long continued draft of a given quantity and the rate at which the surface of the water was found to rise to its original level on the cessation of such draft. With such data I can complete my paper.

Regretting that it is not in my power to attend the meeting, I am,

Very truly, Your obedient servant, J. J. R. CROES.

The Secretary then read a paper contributed by George A. Ellis of Boston, entitled, "Remarks Concerning a Recent Paper on the Flow of Water in a Compound Pipe," suggested by a paper read by L. M. Hastings, City Engineer, Cambridge, Mass., at a former meeting.

A paper on "The Destructive Action of Electrical Currents on Water Pipes," by C. A. Stone and Howard C. Forbes, of Boston, was then read by Mr. Forbes. The subject was discussed further by Mr. I. H. Farnham, of the New England Telephone Co., Mr. Byron I. Cook of Woonsocket, R. I., Mr. Frank L. Fuller, Mr. Howard C. Forbes, Mr. George E. Winslow of Waltham, Mr. Thomas of Lowell, Mr. Fels of Lowell, Mr. John C. Chase and Mr. Sparks of Bangor, Me.

Secretary Coggeshall contributed a paper descriptive of a "Portable Platform to Aid in Excavating Trenches."

Adjourned to evening.

## EVENING SESSION.

The evening session was opened by Hiram F. Mills, civil engineer, member of the State Board of Health of Massachusetts, who read a paper, illustrated by the stereopticon, on "The Lawrence Filter Bed and its Results." The subject was discussed by Mr. Winslow and Mr. FitzGerald.

Mr. George Bowers, city engineer, Lowell, Mass., followed with a paper on "Experiments with Tube Wells at Lowell."

Adjourned.

## MORNING SESSION.

FRIDAY, June 15, 1894.

The committee to nominate officers not being ready to report, the President called for any suggestion or motion in regard to the place where the next annual convention should be held.

THE SECRETARY. It has occurred to me, Mr. President, that we have had in the last few years several invitations to go to Burlington, Vt.; and while this year our friends who reside there have not sent us any special invitation, I feel very certain that if we were to go there we would have a warm reception and a good time. I think our Association is now so large, having nearly 475 members, that if our Burlington associates will arrange a plan for our entertainment we will be glad to pay our own bills and not expect them to be at any expense. I think they will do *their* part if they attend to the arrangements. For the sake of bringing the matter before the meeting I will move that our next annual convention be held at Burlington, Vt.

Mr. Chace seconded the motion, and it was unanimously adopted.

Mr. J. C. Whitney, Water Registrar, Newton, Mass., then read a paper on "Care of Water Meters." The subject was discussed by Mr. J. S. Hodgson, of Medford, and Mr. Peter Milne of Brooklyn, N. Y.

Mr. James E. Tryon, Secretary Fire Commission, Detroit, Mich., read a paper on "What a Water Supply Engineer Can Do in the Fire Department." The reading of this paper closed the morning session.

## EVENING SESSION.

The first business at the evening session was the consideration of applications for membership. The Secretary presented the following additional applications for membership, approved by the Executive Committee.

### MEMBERS ELECTED FRIDAY EVENING, JUNE 15, 1894.

RESIDENT ACTIVE MEMBERSHIP.

John S. Hodgson, Civil Engineer, Wellington, Mass.; Melville A. Sinclair, Superintendent Water Works, Bangor, Me.; T. C Gleason, Superintendent Water Works, Ware, Mass.; Charles A Stone, Electrical Engineer, Boston, Mass.; H. T. Sparks, Superintendent Water Dept. of Public Works Co., Bangor, Me., address Brewer, Me..

NON-RESIDENT ACTIVE MEMBERSHIP.

John S. Davison, Civil Engineer, Pittsburg, Pa.

ASSOCIATE MEMBERSHIP.

I. P. Morris Company, Philadelphia, Pa.

On motion of Mr. Brackett the Secretary was authorized to cast one ballot for the Association, for the applicants as read, and they were declared elected.

Mr. Hall, for the committee appointed to nominate officers for the ensuing year, submitted the following list:

### OFFICERS, 1894-95.

PRESIDENT.

GEO. A STACY, Superintendent Marlborough, Mass.

VICE PRESIDENTS.

JOSEPH L. KENNEY, Superintendent, Lewiston, Me.; CHAS. K. WALKER, Superintendent, Manchester, N. H.; F. H. CRANDALL, Superintendent and Treasurer, Burlington, Vt.; F. F. FORBES, Superintendent, Brookline, Mass.; BYRON I. COOK, Superintendent, Woonsocket, R. I.

SECRETARY.

R. C. P. COGGESHALL, Superintendent, New Bedford, Mass.

TREASURER.

GEORGE E. BATCHELDER, Registrar, Worcester, Mass.

SENIOR EDITOR.

DEXTER BRACKETT, Assistant Engineer Boston, Mass.

JUNIOR EDITOR.

WALTER H. RICHARDS, New London, Conn.

EXECUTIVE COMMITTEE.

JOSEPH E. BEALS, Superintendent, Middleboro, Mass.; JOHN C. WHITNEY, Registrar, West Newton, Mass.; JOHN C. HASKELL, Superintendent, Lynn, Mass.

FINANCE COMMITTEE.

A. R. HATHAWAY, Registrar, Springfield, Mass.; FRANK A. ANDREWS, Assistant Superintendent, Nashua, N. H.; JOHN L. HARRINGTON, Cambridge, Mass.

On motion of Mr. Fiske, the convention voted to accept the report, and authorized the Secretary to cast the ballot of the Association for the officers nominated. This the Secretary did, and they were declared elected to their respective offices for the ensuing year.

On motion of Mr. Coggeshall the Executive Committee was instructed to arrange for a fall field meeting at the White Mountains, to take place the latter part of September.

Mr. E. D. Leavitt, mechanical engineer, of Cambridge, Mass., delivered an address, illustrated by stereopticon views, announcing for his subject, "A Few Examples of High Grade Pumping Engines." He was followed by Mr. Dean.

MR. BRACKETT. Before we adjourn, I wish, as a slight return for the favors which have been shown us during the sessions of the convention, to move that the Secretary be directed to extend the thanks of the Association to the Mayor of the city of Boston, the members of the Water Boards of Boston and Newton, the citizens of Brookline, the Directors of Public Institutions and the Board of Health of Boston, and the West End Street Railway Co. for courtesies extended to the Association during its Thirteenth Annual Convention, and also that the thanks of the Association be extended to Mr. Hiram F. Mills and Mr. E. D. Leavitt for the papers which they have presented. Adopted.

MR. CRANDALL. I move that the thanks of the Association be extended to our retiring president for the manner in which he has performed his duties during the past year. Adopted.

THE PRESIDENT. Gentlemen, I thank you for your kind expression. Before presenting my successor, I wish to say that whatever success we have attained in the past year has been due to the co-operation of officers and members of this Association. So long as you continue your interest in our work our Association will prosper. Again I thank you for your compliment. And now I have the pleasure of presenting to you your new president, Mr. George A. Stacy, of Marlboro, Mass. (Applause.)

PRESIDENT STACY. *Gentlemen of the New England Water Works Association*: I assure you that I thoroughly appreciate the honor that you have done me, in electing me to preside over your deliberations for the coming year. I wish first of all to congratulate the retiring President of this Association upon the successful work that has marked his administration. It must be with considerable satisfaction that he looks back upon the past year, from the time when he assumed the duties of this office until this moment, that he has seen this Association expand and grow and reach out, so that it stands today better, stronger in every way than it was when he took the reins of government.

This Association I consider to be the peer of any association of a kindred nature, in existence. The progressive spirit that has been demonstrated at all times, the enterprise you have shown and the willingness to look on all sides of a question, and to search in every corner for information, experience and experiment to benefit you and those you labor for, was exhibited in the very first part of this meeting. When His Honor the Mayor of Boston, in his very

able address of welcome, having thrown out some hints which seemed to him well for this Association to take into consideration, action was taken almost before his words were cold and an efficient committee appointed to consider his suggestions, and undoubtedly from that committee we shall get good results.

And now all I can say is, that while this honor is extended to me, I do not consider it wholly a personal matter. It is an indication of the loyalty and the generosity and the broad-mindedness of this Association in its willingness to reach out, not only to the large cities, but to the smaller cities and towns, and ask the superintendents from those places to come forward and be recognized; and in my election I see a recognition of these smaller communities throughout the New England States, the members from which in a very large measure furnish the bone and sinew of this organization. May you go on in the future as you have in the past, so conducting this Association as to call into its ranks some of the brightest men that there are in this country in the different professions that pertain to, or have connection in any manner whatever, mechanical or scientific, with water supplies for cities and towns.

And in accepting this office I am sustained by the belief that the same loyal support will be given me and the officers elect of the Association for the ensuing year, that has been extended to our officers in the past, and I trust that at the end of this year we can say that the Association has continued to grow, to reach out and progress and attract the attention of those outside our ranks, who are interested in the subjects with which we have to deal. But if a year from now by any chance this Association is not larger, stronger and better than it is today, I am very sure it will be my fault, and not the fault of the members of this organization. I will ask you to bear with me in any faults I may have, but I assure you that all I can do with my poor ability to forward and increase the value of the work of the Association I shall spare no effort to do. (Applause.)

On motion of Mr. Brackett the convention adjourned.

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The excursions made during the convention were highly enjoyed and more largely attended than usual.

On Friday, June 15th, over 200 members and guests took the Boston & Albany train to Eliot, where carriages furnished through the courtesy of the Boston Water Board were taken and the party conveyed to Echo Bridge and the Newton and Brookline pumping stations. At the latter place a sumptuous lunch was furnished by the citizens of Brookline and Newton, and after a short rest and an inspection of the new triple expansion engine erected by the E. P. Allis Co., carriages were again taken to the Chestnut Hill pumping station of the Boston Water Works, where the twenty million gallon Leavitt pumping engine was seen in process of erection. After a drive around the Chestnut Hill reservoir the party returned by train to Boston.

On Saturday morning a party numbering about 250, on invitation of the city of Boston, embarked on the steamer J. Putnam Bradlee, and spent the day in

a delightful sail around Boston Harbor. Stops were made at the sewage pumping works, where seventy-five million gallons of sewage are pumped each day, and at Fort Warren, and after partaking of a collation served on board, the return was made in time for the afternoon trains. During the return trip on motion of Mr. Holden a vote of thanks was tendered to Mayor Matthews, the Boston Water Board, the Newton Water Board and Assistant City Engineer Brackett, for courtesies extended to the Association during the convention.

Mr. W. S. McNary, of the Boston Water Board, responded with a few pleasant remarks, and the members responded with cheers for their entertainers.

It was the unanimous sentiment that the convention had been one of the most enjoyable ever held by the Association.

## LIST OF EXHIBITS BY ASSOCIATE MEMBERS AT THE CONVENTION

UNDER THE CHARGE OF HAROLD L. BOND.

E. P. Allis Co., Milwaukee, Wis., Illustrations of Pumping Machinery.
Ashton Valve Co., Boston, Mass., Relief Valves.
Randolph Brandt, New York, Packing.
Crosby Steam Gage and Valve Co., Boston, Mass., Gages and Valves.
Coffin Valve Co., Neponset, Mass., Valves and Hydrants.
Frost & Adams, Boston, Mass., Draughting Instruments.
The General Mfg. Co., Brooklyn, N. Y., Illustrations of Pumping Engines.
Hersey Mfg. Co., South Boston, Mass., Meters.
The Hydraulic Construction Co., Driving Well Apparatus.
Michigan Brass and Iron Works, Detroit, Mich., Hydrants and Valves.
Metropolitan Meter Co., Boston, Mass., Meters.
New York Filter Co., New York, Illustrations of Filters.
New England Water Pipe Co., Wakefield, Mass., Lead-lined Iron Pipe.
Neptune Meter Co., New York, Meters.
National Meter Co., New York, Meters.
Perrin, Seamans & Co., Boston, Mass., Tools and Water Works Supplies.
Peet Valve Co., Boston, Mass., Valves.
Ross Valve Co., Troy, New York, Regulator and Reducing Valves.
A. S. Schnee, New York, Illustrations of Pohle Air lift Pump.
Star Pipe Jointer Co., Quincy, Mass., Pipe Jointer.
Anthony P. Smith, Newark, N. J., Branch Tapping Machine.
Thomson Meter Co., Brooklyn, N. Y., Meters.
Taunton Locomotive Mfg. Co., Taunton, Mass., Lead Furnace and Service Box.
Union Water Meter Co., Worcester, Mass., Meters.
Henry R. Worthington, New York, Meters.
Fuel Gas and Mfg. Co., Pittsburg, Pa., Meters.

## ATTENDANCE AT THE CONVENTION.

### ACTIVE MEMBERS.

Everett L. Abbott, New York city.
Charles F Allen, Hyde Park, Mass.
Solon M. Allis, Madison, N. J.
Frank A. Andrews, Nashua, N. H.
Charles H. Baldwin, Boston, Mass.
Richard Baldwin, Terryville, Conn.
Lewis M. Bancroft, Reading, Mass.
Frank A. Barbour, Brockton, Mass.
George H. Barrus, Boston, Mass.
George E. Batchelder, Worcester, Mass.
Joseph E. Beals, Middleboro, Mass.
Nathan B. Bickford, Boston, Mass.
William R. Billings, Taunton, Mass.
George Bowers, Lowell, Mass.
Dexter Brackett, Boston, Mass.
Arthur W. F. Brown, Fitchburg, Mass.
Geo. A. P. Bucknam, Norwood, Mass.
John M. Burleigh, South Berwick, Maine.
James Burnie, Biddeford, Maine.
George F. Chace, Taunton. Mass.
E. J. Chadbourne, Wakefield, Mass.
Charles E. Chandler, Norwich, Conn.
John C. Chase, Wilmington N. C.
Frederick W. Clark, Brighton, Mass.
Harry W. Clark, Lawrence, Mass.
Freeman C. Coffin, Boston, Mass.
R. C. P. Coggeshall, New Bedford, Mass.
H. W. Conant, Gardner, Mass.
Byron I. Cook, Woonsocket, R. I.
Henry A. Cook, Salem, Mass.
F. H. Crandall, Burlington, Vt.
George K. Crandall, New London, Conn.
George E. Crowell, Brattleboro, Vt.
L. E. Daboll, New London, Conn.
Geo. S. Davison, Pittsburg, Pa.
Albert B. Drake, New Bedford, Mass.
Charles E. Drake, New Bedford, Mass.
Eben R. Dyer, Portland, Maine.
Horace L. Eaton, Somerville, Mass.
W. P. Ellison, Newton, Mass.
George E. Evans, Boston, Mass.
Frank L. Fales, Lawrence, Mass.
B. R. Felton, Marlboro, Mass.
Wilbur D. Fiske, Boston, Mass.
Desmond FitzGerald, Brookline, Mass.
F. F. Forbes, Brookline, Mass.
Z. R. Forbes, Brookline, Mass.
William E. Foss, Brighton, Mass.
John R. Freeman, Boston, Mass.
Frank L. Fuller, Boston, Mass.
Geo. W. Fuller, Lawrence, Mass.
J. C. Gilbert, Whitman, Mass.
L. L. Gerry, Stoneham, Mass.
Albert S. Glover, Boston, Mass.
T. C. Gleason, Ware, Mass.
Andrew B. Goodier, Southbridge, Mass.
X. H. Goodnough, Boston, Mass.
J. A. Gould, Jr., Boston, Mass.
Frederick W. Gow, Medford, Mass.
E. H. Gowing, Boston, Mass.
Richard A. Hale, Lawrence, Mass.
Frank E. Hall, Quincy, Mass.
E. A. W. Hammatt, Boston, Mass.
John L. Harrington, Cambridge, Mass.
John C. Haskell, Lynn, Mass.
L. M. Hastings, Cambridge, Mass.
A. R. Hathaway, Springfield, Mass.
Louis Hawes, Boston, Mass.
William B. Hawes, Fall River, Mass.
Ansel G. Hayes, Middleboro, Mass.
James H. Higgins, Providence, R. I.
John S Hodgson, Medford, Mass.
Horace G. Holden, Nashua, N. H.
Horatio N. Hyde, Newtonville, Mass.
Daniel D. Jackson, Newtonville, Mass.
David B. Kempton, New Bedford, Mass.

Joseph L. Kenney, Lewiston, Maine.
Willard Kent, Woonsocket, R. I.
Patrick Kieran, Fall River, Mass.
Perry Lawton, Quincy, Mass.
R. S. Lea, Montreal, P. Q.
Wilbur F. Learned, Watertown, Mass.
Joseph A. Lockwood, Yonkers, N. Y.
A. E. Martin, South Framingham, Mass.
Cyrus B. Martin, Norwich, N. Y.
Josiah S. Maxcy, Gardiner, Maine.
William McNally, Marlboro, Mass.
W. S. McNary, Boston, Mass.
D. S. Merritt, Tarrytown, N. Y.
T. D. Miller, Norwich, N. Y.
James W. Morse, Natick, Mass.
Thomas Naylor, Maynard, Mass
Edward C. Nichols, Reading, Mass.
Frank L. Northrop, Milford, Mass.
Albert F. Noyes, Boston, Mass.
A. G. Pease, Spencer, Mass.
John H. Perkins, Watertown, Mass.
John F. Philbin, Clinton, Mass.
George S Rice, Boston, Mass.
Walter H. Richards, New London, Conn.
George J. Ries, Weymouth Centre, Mass.
J. W. Ringrose, New Britian, Conn.
W. W. Robertson, Fall River, Mass.
Henry W. Rogers, Haverhill, Mass.
Daniel Russell, Everett, Mass.
A. H. Salisbury, Lawrence, Mass.
Arthur F. Salmon, Lowell, Mass.
Willard T. Sanborn, Dover, N. H.
William T. Sedgwick, Boston, Mass.
John D. Shippee, Holliston, Mass.
Melville A. Sinclair, Bangor, Maine.
H. O. Smith, Leicester, Mass.
Edwin W. Snow, Orange, Mass.
H. T. Sparks, Brewer, Maine.
George A. Stacy, Marlborough, Mass.
James H. Stanwood, Boston, Mass.
Frederic P. Stearns, Boston, Mass.
Eugene S Sullivan, Boston, Mass,
Charles H. Swan, Boston, Mass.
Lucian A. Taylor, Boston, Mass.
Robert J. Thomas, Lowell, Mass.
William H. Thomas, Hingham, Mass.
M. M. Tidd, Boston, Mass.
S. Everett Tinkham, Boston, Mass.
D. N. Tower, Cohasset, Mass.
James E. Tryon, Detroit, Michigan.
Charles K. Walker, Manchester, N. H.
Sidney G. Walker, Boston, Mass.
George C. Whipple, Brighton, Mass.
John C. Whitney, West Newton, Mass.
William F. Williams, New Bedford, Mass.
Horace B. Winship, Norwich, Conn.
Frederic I. Winslow, Boston, Mass.
George E. Winslow, Waltham, Mass.
Timothy Woodruff, Bridgeton, N. J.
W. G. Zick, Waterford, N. Y.

Total active membership present, 136.

HONORARY MEMBERS.

E. R. Jones, Boston, Mass.
*The Engineering News*, of New York City, by M. N. Baker.
*The Engineering Record*, of New York City, by Charles J. Underwood, Jr.
*Fire and Water*, of New York City, by F. W. Shepperd and Peter Milne.

Total honorary membership present, 5.

ASSOCIATE MEMBERS.

The Edward P. Allis Co., of Milwaukee, Wis., by John H. Lewis and E. L. Rogers.
Ashton Valve Co., Boston, Mass., by C. W. Houghton.
James M. Betton, Boston, Mass.

The George F. Blake Mfg. Co., New York City, by James T. Boyd.

Boston Lead Mfg. Co., Boston, Mass., by C. A. Fairbairn.

Randolph Brandt, New York City.

Chadwick Lead Works, Boston, Mass., by E. D. Ingraham and A. H. Broderick.

Chapman Valve Mfg. Co., Indian Orchard, Mass., by Edward L. Ross and H. R. Dalton.

Coffin Valve Co., Boston, Mass., by F. E. Adams.

Crosby Steam Gauge and Valve Co., Boston, Mass., by E. H. Eberle.

Deane Steam Pump Co., Holyoke, Mass., by A. M. Pierce and F. H. Hayes.

Frost & Adams, Boston, Mass., by H. A. Lawrence and E. J. White.

Fuel Gas and Mfg. Co., Pittsburg, Pa., by A. G. Holmes.

F. B. Hawkins, New York City.

William H. Gallison, Boston, Mass., by A. H. Davis.

The General Mfg. Co., Brooklyn, N. Y., by Louis A. Pollard.

Hersey Manufacturing Co., Boston, Mass., by J. A. Tilden, J. E. Spofford and A. A. Blossom.

Hydraulic Construction Co., New York City, by W. D'h Washington, A. R. White and M. R. Rider.

Henry F. Jenks, Pawtucket, R. I.

Metropolitan Meter Co., Boston, Mass., by James J. Morgan.

I. P. Morris Co., Philadelphia, Pa., by H. W. Hand.

National Lead Co., Boston, Mass., by C. P. Coggeshall.

National Meter Co., New York City, by John C. Kelley.

New York Filter Co., by W. M. Deutsch, New York City.

Peet Valve Co., Boston, Mass., by S. B. Adams.

Perrin, Seamans & Co., Boston, Mass., by H. L. Bond.

William J. Ranton, Syracuse, N. Y.

Ross Valve Co., Troy, N. Y., by L. R. Stanley.

Alexander E. Schnee, New York City, by S. W. Titus.

Anthony P. Smith, Newark, N. J., by A. P. Smith and W. H. Van Winkle.

Star Pipe Jointer Co., Quincy, Mass., by W. G. Spear.

Taunton Locomotive Manufacturing Co., Taunton, Mass., by W. R. Billings.

Thomson Meter Co., Brooklyn, N. Y., by E. T. Ivins, S. D. Higley and H. C. Folger.

Union Water Meter Co., Worcester, Mass., by George H. Carr and J. P. K. Otis.

Walworth Mfg. Co., Boston, Mass., by W. P. F. Ayer, E. H. Rice and J. H. Eustis.

William Wolfendale, Fall River, Mass.

R. D. Wood & Co., Philadelphia, Pa., by W. E. Newhall.

The George Woodman Co., Boston, Mass., by J. J. Stockdon and H. A. Gorham.

H. R. Worthington, South Brooklyn, N. Y., by William O. Webber and George B. Ferguson.

Total Associate Membership present, 56.

GUESTS.

A. M. Allen, Haverill, Mass.
Mrs. A. M. Allen, Haverill, Mass.
Richard B. Allen, Lowell, Mass.
Mrs. S. M. Allis, Madison, N. J.
Master Allis, Madison, N. J.
Mrs. L. M. Bancroft, Reading, Mass.
Thomas Banks, Marlboro, Mass.
T. Howard Barnes, Medford, Mass.
William T. Barnes, Boston, Mass.
John H. Barrows, NewBedford, Mass
Mrs. G. E. Batchelder, Worcester.
Miss Batchelder, Worcester, Mass.
Mrs. J. E. Beals, Middleboro, Mass.
H. E. Bothfield, Newton, Mass.
M. F. Brennan, Lowell, Mass.
Edwin C. Brooks, Cambridge, Mass.
Frederick Brooks, Boston, Mass.
Leroy Brown, Waltham, Mass.
Hon. Stephen A. Brownell, Mayor, New Bedford, Mass.
Mrs. Stephen A. Brownell, New Bedford, Mass.
T. Byrne, Marlboro, Mass.
John F. Callahan, Norwood, Mass.
J. M. Charnoch, South Boston, Mass.
Mrs. J. M. Charnoch, South Boston, Mass.
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Mrs. F. W. Clark, Boston, Mass.
Mrs. F. C. Coffin, Boston, Mass.
Mrs. C. P. Coggeshall, Boston, Mass.
J. P. Collins, Marlboro, Mass.
W. R. Copeland, Lawrence, Mass.
George H. Cox, Cambridge, Mass.
Mrs. F. W. Coy, Boston, Mass.
Miss O. S.Crowell, Middleboro, Mass
Miss. C. H. Davis, Boston, Mass.
Joseph Dame, Salem, Mass.
H. D. Degan, Newton, Mass.
Miss Donavan, Marlboro, Mass.
W. D. Doyle, Marlboro, Mass.
M. J. Dwyer, Boston, Mass.
Mrs. M. J. Dwyer, Boston, Mass.
Mrs. Horace L. Eaton, Somerville, Mass.
August Fels, Lowell, Mass.
J. A. Fenno, Mayor, Newton, Mass.
F. B. Forbes, Lawrence, Mass.
H. D. Forbes, Boston, Mass.
Mrs. F. L. Fuller, Wellesley Hills, Mass.
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H. F. Gibbs, Natick, Mass.
Mrs. Jason Giles, Indian Orchard, Mass.
Mrs. A. S. Glover, West Newton, Mass.
Miss Bessie Glover, West Newton, Mass.
Mrs. H. A. Gorham, Boston, Mass.
H. H. Goss, Brockton, Mass.
Mrs. F. W. Gow, Medford, Mass.
Mrs. J. A. Gould, Boston, Mass.
Miss Greenwood, West Newton, Mass.
Mrs. R. A. Hale, Lawrence, Mass.
Mrs. H. W. Hand, Philadelphia, Pa.
C. W. Harris, Jr., Wakefield, Mass.
Samuel Harrison, Boston, Mass.
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G. W. Hawkins, Boston, Mass.
Mrs. F. H. Hayes, Boston, Mass.
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C. F. Holyoke, Marlboro, Mass.
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J. W. Horton, Trenton, N. J.
John Hurley, Salem, Mass.
M. C. Hyde, Springfield, Mass.
Mrs. J. F. Kelley, New Britain, Ct.
Mrs. D. B. Kempton, New Bedford, Mass.
C. W. Knapp, Newton, Mass.
I. C. Knowlton, Watertown, N. J.
E. D. Leavitt, Cambridge, Mass.
John A. Loring, Everett, Mass.
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J. W. McDonald, Marlboro, Mass.
Mrs. W. S. McNary, Boston, Mass.
W. D. Meldon, New York City.
Hiram F. Mills, Lawrence, Mass.
John W. Murphy, Malden, Mass.
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Miss Myra E. Winslow, Waltham, Mass.
Mrs. F. I. Winslow, Malden, Mass.
H. D. Woods, West Newton, Mass.

Number of guests, 125.
Total attendance registered, 320.

# ELECTROLYSIS OF WATER PIPES.

BY

CHARLES A. STONE AND HOWARD C. FORBES.

[Read June 14, 1894, Boston, Mass.]

## THE DESTRUCTIVE ACTION OF ELECTRIC CURRENTS ON WATER PIPES.

History: The effect of electrolytic action in corroding water and gas pipes in cities where electric railways have been adopted, is a subject which is now attracting a good deal of attention. It is impossible as yet to determine the extent of the injury resulting from this cause, but sufficient evidence is at hand to show that it is a matter worthy of most careful consideration.

Up to the time that single trolley systems of electric railways were generally adopted, no considerable amount of electricity flowed through the earth, except such as might leak away from the accidental grounding of electric lighting wires. With the first introduction of electric roads, the rails were adopted as a path for conveying the current from the cars back to the power station, and it was soon found that the joints, even when thoroughly bonded, had so great a resistance that a portion of the current flowed from the rails into the earth. In many cases, it was found that the conductivity of the circuit as a whole, could be materially increased by connecting the rails at various points with the moist earth, allowing the current to seek its own way from there to the power station. Until recently most electrical engineers have supposed the body of the earth to be so good a conductor, that the quantity of electricity which could pass through it safely was practically unlimited. Recent investigation, however, has shown that the earth is in reality very unreliable as a conductor; and that only under certain favorable conditions, is its resistance such as to permit the passage of currents of any considerable magnitude.

This fact was brought to the attention of the public about two years ago, when it was discovered that in certain places in Boston,—and in other cities where electric roads had been adopted,—differences of potential existed between adjacent pipes. It was found in one place that a steam pipe and a water pipe in the same building, not more than twelve inches a part, had a difference of pressure between them, of about eight volts; and that upon connecting the two with a stout piece of wire, a sufficient current flowed, to bring the wire to a white heat. In one or two instances advantage was taken of their conditions and small motors were driven from this source of power. Such a state of affairs was considered extremely dangerous from a fire point of view, and accordingly the subject was investigated by the electrical inspectors of the Boston Board of Fire Underwriters and others.

## EVIDENCE THAT ACTION IS OCCURRING.

The action of electrolysis is to corrode the pipes at the point where the current leaves them. This corrosion as we shall show, is not uniformly distributed over the surface, but is quite irregular, usually producing deep pits. The

result is therefore an acceleration of the natural decay of the pipes,—the rate of corrosion increasing as the current flowing out of the pipe becomes greater.

Evidence of injury to water and gas pipes by electric action, would therefore naturally be expected to take two forms ; one the premature giving out of the pipes, the other, an increased rate of renewals and repairs.

Evidence of the former sort would presumably be the first to develop itself, and there are already many examples of this action, which it will be interesting to consider.

But in this connection we must guard against one point which might lead us astray. So much attention has been given of late to electrolytic action, that the premature decay of pipes from any cause, is likely to be attributed to electricity.

Now the fact that the water pipes are being destroyed is nothing new ; as natural causes are sufficient to limit the life of any pipe. Nor does this rusting take place at a uniform rate ; for in some sections a pipe will last for years, while in other sections, where there is no possibility of electrolytic action, the character of the soil may be such, that the pipes will give out in a much shorter time.

Although the injurious action of electric currents is to hasten natural corrosion, nevertheless the fact that a pipe gives out soon after it is laid, is not in itself positive evidence of electrolysis. A careful study of pipes taken from various localities and of specimens which have been produced artificially in the laboratory, has shown that it is very difficult to distinguish between ordinary chemical action and electrolysis.

The appearance of the scale formed on an iron pipe originally subjected to oxidation, and afterwards prevented from oxidation by becoming the negative pole of an electrolytic couple, enables us to determine pretty definitely where natural decay has been arrested by a current of electricity flowing into a pipe. There is, however, apparently no mark showing as clearly where decay has been accelerated by the passage of the current out of a pipe. This gradual deterioration, would appear only in the course of years, and the evil might assume very serious proportions before the evidence became convincing.

We have made careful inspections of pipes taken from a large number of cities, and in most cases we find as stated before that the specimens have the appearance of being acted upon by natural causes, the rate of decay simply being accelerated by the electric current. A few instances, however, have been brought to our attention where no natural decay whatever is apparent ; this sample for instance, is one which was taken from the ground in the vicinity of the power station at Minneapolis. [Exhibited samples.] It is a portion of a gas post service pipe, which led from the gas main running in a direction at right angles to the track. The pipe was in use only about six months, and an inspection will show that no rusting is apparent. Another specimen obtained at Nashville, Tenn., appears quite different, showing the fibrous structure of the metal. This is a portion of a service pipe, and was probably in the grounds several years previous to the time of excavation. It is impossible to state positively whether decomposition in this case was due mainly to electrolytic

action, but the natural inference would be that it was, for the reason that the remaining pipes of the system which were laid at the same time, have in most places been unaffected , while in the vicinity of the electric roads very considerable damage has been done.

The class of action that has been most seriously apprehended in Boston is of an entirely different character from that observed in Minneapolis and Nashville. It has not been definitely proven as yet, that the action on the water pipes here is sufficiently serious to menace the system ; but the absence of extensive direct evidence of destruction can by no means be interpreted as proving the absence of action.

The soil in this city is presumably saturated to a great extent with salt water, which is a reasonably good conductor of electricity, and which would tend to induce a uniform passage of current from the pipes at all points, instead of a passage of a large amount of current at a few places, as evidently occurs at Nashville, Minneapolis and one or two other cities, where we have made inspections.

Now although in the cases which we have mentioned and in others, the rapid deterioration of the pipes has indisputably been connected with the return currents of electric roads, yet arguments are still advanced to explain the action upon other grounds than electrolysis ; such as the permeation of the soil with illuminating gas, etc.

In order therefore, to be able to meet all such arguments as these and to put the responsibility in this matter absolutely where it belongs, we are conducting at our laboratory a series of experiments, with a view to distinguishing positively between electrolytic action, and all other causes of rusting. By this means we shall be able in most cases to determine by inspection, just what part electrolytic action has played in the deterioration of the pipes. When this is done we shall be in a better position to pass judgment upon the merits of the various schemes which have been proposed as remedies, for it is absolutely essential to be able to determine from the pipes themselves just how they have been affected by electrolytic action: (i. e. when the pipe was positive to the earth around it); and the other pipe would show the action when the current flowed into it (i. e. when the pipe was negative to the earth around it.)

Now, common salt by electrolysis yields chlorine at the surface where the current leaves the pipe. This corrodes the pipe rapidly. Where the current enters the pipe no corrosive action takes place. These well known facts were borne out by our experiments, which developed, moreover, a point of great practical importance, namely, that the tendency of electrolytic action is to become localized ; for the pipes were deeply pitted in spots instead of being corroded uniformly over the surface.

Thus in a typical case a wrought iron pipe 1 inch in diameter lost 7.6 per cent. in weight, but the pipe was so badly pitted that when turned off in a lathe to the bottom of the pits, the actual damage was 63 per cent. This shows, of course, that, owing to the formation of the pits, the corrosion had gone in spots to about eight times the depth that it would have gone if it had been uniform over the surface.

At the request of Mr. William Jackson, City Engineer, we have conducted during the past year an elaborate series of tests for the purpose of determining whether or not electrolytic action had assumed serious proportions in Boston, and what remedies it would be wise to apply.

The result of this investigation has recently been embodied in a report, and in order to give a clear idea of what has been done, we will give a few selections.

NATURE OF ELECTROLYTIC CORROSION—EXPERIMENTALLY STUDIED.

"It was important not only to demonstrate that currents of electricity, flowing into or out of iron and other pipes, would produce serious corrosion, but to determine just what the character of the injury would be. For this purpose experiments were made in our laboratory, reproducing various conditions in the soil, and the effects were carefully studied.

Samples of commercial pipes were placed by pairs in sand and moistened with salted water. In this respect they were practically under the conditions of pipes buried in the streets.

Measured currents of electricity, at constant pressure, were passed from one pipe to the other of a pair. Thus one pipe would show the action when the current flowed out of it.

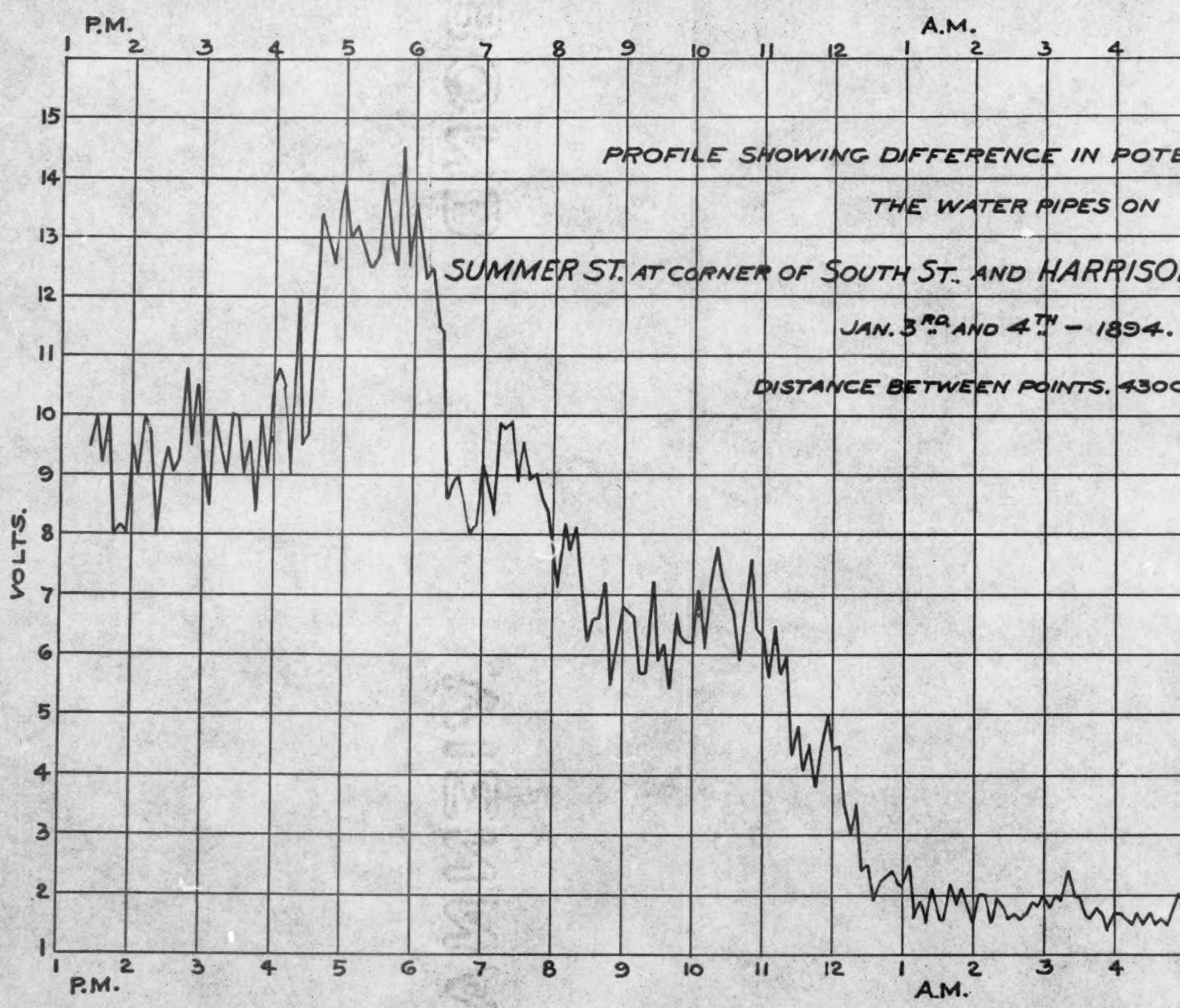
EXISTENCE OF NECESSARY CONDITIONS FOR ELECTROLYSIS.

If we could ascertain by direct means whether currents of electricity were flowing from the earth into the pipes or from the pipes into the earth, how large these currents were and how they were distributed over the pipe surface, we should then have a direct means of estimating the injury done to the pipes; but these three points are from the nature of the case very difficult, if not impossible, to determine, even roughly. It is essential, therefore, to proceed indirectly by showing that the underground electrical conditions in the city are such as either to render destructive electrolysis likely, or to render it unlikely. We have done so as follows:

By extended tests we have shown that the distribution of electrical pressure in the earth in Boston is such that there must be a continual, and at times a strong flow of electricity through the earth, from nearly all parts of the city toward the West End Power Station on Albany Street.

In as much as water and gas mains are imbedded broadcast in the soil and are much better conductors than the soil, bulk for bulk, a portion of these currents must traverse the pipes; and since there is practically no metallic connection between the pipes and the railway returns, the current must enter and leave the pipes by way of the earth. Wherever the current thus enters or leaves a pipe electrolytic action takes place. This produces corrosion where the current leaves the pipe.

This inference is confirmed by multiplied tests which show that the piping is almost everywhere at a potential different from the earth around it, and from the nearest railway tracks. Under such conditions currents must be flowing either to or from the pipes. These differences are, moreover, not constant, but are continually fluctuating, which adds to the certainty of the flow of current.


P.M.
A.M.
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4
15
14
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3
2
1
VOLTS.
PROFILE SHOWING DIFFERENCE IN POTE
THE WATER PIPES ON
SUMMER ST. AT CORNER OF SOUTH ST. AND HARRISO
JAN. 3RD AND 4TH - 1894.
DISTANCE BETWEEN POINTS. 4300
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4
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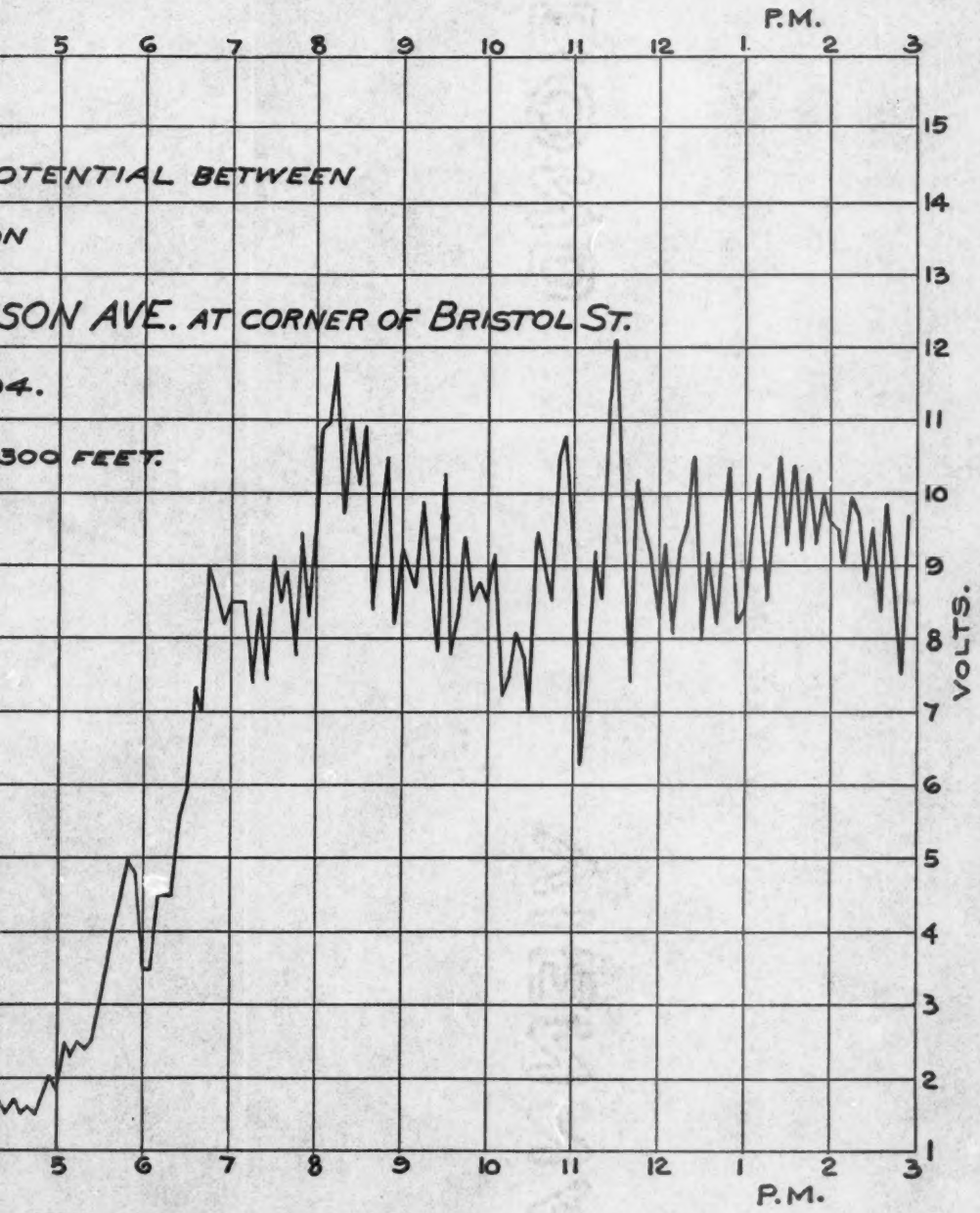
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OTENTIAL BETWEEN
ON
SON AVE. AT CORNER OF BRISTOL ST.
04.
300 FEET.
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
VOLTS.
5 6 7 8 9 10 11 12 1 2 3
P.M.

The demonstration of the continual flow of current through the earth to the power station was made by measuring the difference between the electrical pressure in the water piping at a point near the station and at other distributed points. These outlying points showed always higher pressures than the one near the station.

To demonstrate that these differences of potential are due mainly to the return currents of the electric roads, and to study more completely the character of these currents, an attempt was made to construct a potential map of the city. To obtain the necessary data for such a map wires were strung about the city, radiating from a centre of distribution where readings could be taken. This centre of distribution was chosen on East Street. From that point wires were run along Albany Street to the Power Station, across the city to the Common, and thence to the river at the foot of Charles Street, along Atlantic Avenue to a point near Long Wharf, and tap circuits from these lines extended to several other points. The terminals of all were grounded so that, by simply connecting in a voltmeter at East Street the difference of potential between any two points could be read. Measurements were taken continuously at intervals of thirty seconds throughout the day, and curves plotted with the voltage as ordinates and time as abscissae. The average of a number of days shows that the voltage increases as the number of cars in service increases and the fluctuations are in direct proportion to the load. The accompanying curve will serve to illustrate these facts. This curve is plotted from readings taken between Summer Street and Engine House No. 3, and shows that during the night up to about 5 o'clock in the morning, no appreciable difference of potential exists. As soon, however, as more cars begin to run, a difference of potential between these two points appears, and this difference increases gradually until it assumes a maximum in the morning at about 8 o'clock. Then the difference decreases until about 10:30, when it increases again, reaching a maximum at about 11:30. After this there is a gradual falling off, reaching a minimum in the middle of the afternoon, and then another maximum point at about 5:30. Then there is a slight fall, and another maximum at about 7:30 in the evening, and finally a minimum, followed by a maximum at about 10:30.

From this curve it is easy to trace the movements of the people in the city. The first maximum occurs at about 8 o'clock, when the majority of people are on their way to the offices and shops. The next maximum occurs at noon and the next is reached when the people are on their way home from work at about 6 o'clock. The next point of high potential occurs at about 7:30 o'clock, when they are on their way to the theatres and other places of amusement, and the last maximum is reached at 10:30, about the time that theatres close and people are returning home. These periodical fluctuations occur with such precision, that it would be possible for an observer stationed at a point where what was going on without could not be seen, to tell approximately the hour of the day from these fluctuations.

This shows conclusively that the difference of potential existing in the earth, is due mainly, if not entirely, to the flow of current from the electric cars

back to the power station. A large number of readings of differences of potential taken at various points throughout the City of Boston show a maximum of about 18 volts. This difference occurred between the power station and a point some 5,000 feet away, being in line with what is probably the heaviest flow of current back to the station. A number of readings were taken between different points of the city situated about equally distant from the power station which showed no difference of potential whatever, except at intervals, the difference depending upon the relative position of cars upon the adjacent lines, and often changing rapidly from positive to negative.

We are not aware that systematic measurements have been made in any other city than Boston, so we are unable to state whether or not the differences that exist in the cities which have been more seriously affected are greater than here. The natural inference would be that this is the case, and a few measurements taken by us in Peoria for the purpose of mapping out a small district, seem to show that in places where the electric railway company has not been so careful in bonding its return circuit, the flow of currents through the earth is much greater.

In one or two cities which have been brought to our notice the surface differences of potential appears to be very much greater than here, but this is probably due to the general character of the soil. At Nashville, Tenn., for instance, there is only a few feet of soil below the surface of a greater portion of the city, everything below that being a solid bed of rock. In this case the current naturally flows through the thin layer of soil at its point of greatest conductivity; and hence the current density per unit area must necessarily be increased, which would increase correspondingly the difference of potential from point to point. This probably accounts in part for the rapid action in that city.

THE EFFECT OF ELECTRIC CURRENTS UPON PIPES WITH POOR JOINTS.

There can be no doubt that the pipes of this city are at present carrying currents of electricity. This is shown by the fact that we find a continuous difference of potential between the hydrants and the ground; for, if the pipes did not carry away the electricity this difference of potential would immediately fall.

Now, while it may be possible to control the polarity of the pipes, it is highly improbable that the conditions will ever be made such that the pipes will become exactly neutral. Unless some scheme is developed which is radically different from any yet suggested, currents of electricity in the pipes cannot be prevented, although they may be considerably reduced. For in the system now in use in this city, or in any single trolley system which uses the uninsulated rails as a part of the return circuit, it is inevitable that some portion of the current must pass back to the power station by way of the pipes, as we have pointed out before. Nothing but a system which is insulated from the ground throughout can prevent differences of potential in the ground and the consequent flow of electricity through the pipes. Again, in some remedies which have been suggested, it is proposed actually to use the pipes as a part of the return circuit, so forcing a considerable quantity of electricity to pass through them.

Now, if the current passing along the pipe meets a joint which is electrically poor, that is, a joint which offers considerable resistance to the passage of the current, there will be an injurious action on the pipe, and for this reason: The electricity will not stop at the poor joint, but will divide, part going through the joint, and part passing around it through the earth on the outside or through the water on the inside. The usual corroding action takes place on the inside as well as on the outside of the pipe wherever the current leaves it. This we have shown conclusively by tests conducted at our laboratory.

Hence we must determine the conditions under which this injury from the current passing around a poor joint, becomes a minimum, or how it can be entirely prevented.

With regard to new piping, the question is simply whether lead joints can be made of sufficiently low resistance to hold practically the whole current in the pipes, and not to allow any appreciable part of it to pass around the joints.

In old pipes, however, which have been for years under ground, many joints of high resistance will undoubtedly be found, at which serious injury to the pipes would be occasioned; but it will be possible in most cases, by measuring the fall of potential along the pipe, to locate these joints.

But, besides the injury from corrosion at the joint there is another point which is likely to become of vast importance, and which will render extreme care necessary. This is the possible contamination of the water supply by the salts of iron or lead which would be formed if electrolysis should take place inside the pipe.

For example, suppose in a certain section of the city a supply pipe leading to a building at some distance from the mains does not happen to be used; or suppose a section of the city is shut off during the repairs; or suppose for any reason the circulation of water becomes sluggish; then if there happens to be a joint in this part which is electrically poor, and through which a current of electricity is forced to pass, we should expect the following result: The current would divide, part passing around the poor joint through the water on the inside, as well as through the earth on the outside, as we have explained above. The usual action which occurs when the current leaves a metal will take place on the inside of the pipe, that is, the pipe will be corroded, and if the pipe be iron, salts of iron will be formed and remain in the water. These salts of iron will tend to increase the conductivity of the water, which will cause a greater current to leave the pipes, which, in its turn, will increase correspondingly the rate of formation of the iron salts.

Now, under this action, the water will soon become exceedingly impure, and these impurities by diffusion, will penetrate back into the main piping system.

By this means it is not at all improbable that the water in a portion of the city might be rendered absolutely unfit for many industrial purposes, or should salts of lead be formed no one can foretell how serious the result might be, if the water were used for drinking.

Possibilities :

In the course of the study which we have given to this problem, we have developed a number of theories which seem to us sufficiently probable to warrant a thorough investigation.

One in particular is especially worthy of mention as it gives promise, if properly worked out, of results which would be of great commercial value. This is the theory that by properly using the ground currents, they can be made to protect whole water piping systems from rusting, and thus greatly lengthen the life of the pipes.

It is a well known fact that in the electrolytic cells which are used for such purpose as the decomposition of common salt, the negative electrode is completely protected from the corroding action of the salt solution in which it is immersed.

Again in electroplating the main principle depends upon the formation of a metallic deposit upon the negative electrode with a consequent increase in the weight.

We would also cite the well known methods of protecting boilers or iron tanks from rusting, by means of a plate of zinc suspended in the liquid, which in reality serves to protect the tank in the same manner,—namely by rendering the iron of the tank negative to the liquid which it contains.

Now the conditions existing throughout the city do not differ essentially from those of the electrolytic cells. The voltage is usually somewhat less in the ground, although at times it may be greater. The chemicals involved are of a greater variety, and the action takes place in damp earth instead of in a free liquid. But these differences do not affect the principles of electrolysis.

All the experiments which we have made upon iron and lead pipes, reproducing the conditions of electrolysis in the soil have shown that while the positive pipes were badly corroded, and in most cases practically destroyed, the pipes which served as the negative electrode were in no case injured. Had the pipes been allowed simply to remain in the sand, with no electricity passing between them, both electrodes would have been considerably rusted, as the sand was damp and contained a small quantity of common salt and carbonate of soda.

From this reasoning we feel confident when the pipes form the negative electrode, in other words, when they are negative to the earth surrounding them, that they are not only, not injured by electrolysis, but that they are actually being protected from natural corrosion. That is, new pipes which have just been put under ground, are better protected from corrosion when they are negative to the ground, than by any of the so-called "Anti-Rust" processes yet devised. And in old pipes which have been under ground for years, all further rusting is stopped as soon as they become negative to the ground.

Whether the pipes are really thus protected and to what extent this protection might be carried, are points which we consider worthy of careful investigation. The few inspections which we have already made upon excavations about the city seem to confirm the above theory.

We have, therefore, outlined a series of tests to find the minimum difference of potential which will oppose natural corrosion.

### Remedies :

Let us now consider the schemes that have been proposed as solutions for the problem, which for convenience we will divide into three classes.

1. Those accomplishing the result completely.
2. Those giving partial relief.
3. Those which are useless.

### 1. Complete Remedies :

The remedies which would completely do away with the injury to the pipes are :

(*a*) Double trolley system.
(*b*) Storage battery system.
(*c*) Completely insulating the pipes.
(*d*) And possibly the use of the alternating current.

### Double Trolley and Storage System :

The double trolley system, which is self explanatory, furnishes current to the cars by one trolley wire and takes it back again to the power station by another. The storage battery system is complete in itself. Hence by these two methods no current is allowed to enter the ground, and so no injury to the pipes could result. But practical difficulties arise in the operation of both of these systems which prevent the general use of either of them for the present.

The double trolley is inconvenient to handle, and necessitates complicated overhead construction. Storage batteries are heavy, and are not as yet sufficiently developed for commercial use.

### Insulating the Pipes :

By the method of completely insulating the pipes, it is evident that the electric currents could not enter them, and therefore could have no effect upon them. For doing this it has been proposed to lay a double piping system consisting of the iron pipes enclosed in drain pipes, or to lay the iron pipes in wooden boxes containing tar or sawdust. This remedy would be successful only in so far as the insulation was complete. Some application of it might perhaps be made to new pipes, but it would hardly be feasible to apply it to a piping system already in the ground. Should this method be attempted one point in particular would be essential to its proper working. The outer system of piping must be absolutely water tight, or the whole scheme would be rendered useless; for should moisture collect inside the insulating pipe, electrolytic action would immediately begin; and as the collection of moisture is likely to take place in one spot, the electrolytic action would be greatly localized, and would therefore take place at a rapid rate. In this connection it might be well to note that pipes which have been laid with an outer covering of cement, have not been at all protected, inasmuch as when the cement becomes moist, electrolytic action takes place through it.

ALTERNATING CURRENT:

The alternating current might prove a solution of the difficulty, although this is still questioned by some authorities. At present the alternating motor is not sufficiently developed to render this system practicable.

REMEDIES GIVING PARTIAL RELIEF:

The remedies which have been suggested with the idea of reducing the action to a minimum are:

(*a*) Very heavy returns from the tracks to the power station with good bonds between the rails; also returns from sections of track, every 500 feet along the route.

(*b*) Three wire system.

(*c*) Insulating the tracks.

HEAVY RETURNS:

The better the system of ground returns the less will be the current flowing through the earth, as it will be confined mainly to these returns; but as we have brought out above, this can never do away entirely with the electric currents in the pipes. Heavy returns accompanied by good bonds have undoubtedly diminished the trouble in this city, but have by no means stopped it, and until further experiments have been made, it is difficult to say how much benefit has been derived. To thoroughly carry out this system the cost for copper returns is likely to be enormous.

THREE WIRE SYSTEM:

With regard to the three wire system little is actually known, as it has not as yet been sufficiently tested in practical operation. Undoubtedly the trouble would be considerably reduced by this means, but as the system practically never could be balanced perfectly, currents in the earth could not be prevented. And in addition to this, the action would be greatly scattered, and made so indefinite that it would be impossible to tell anything about it.

INSULATION OF TRACKS:

A perfect insulation of the tracks is impossible inasmuch as the top surface must always be exposed, so the scheme of insulating the tracks and connecting them by insulated copper returns to the power station, would at best only tend to reduce the injury. So far no suitable material has been devised, and it is doubtful if any material would prove sufficiently durable on account of the severe treatment to which it would be subjected.

3. SCHEMES WHICH ARE USELESS:

(*a*) Connections from the track to the pipes.

(*b*) Bringing the pipes to uniform potential by the cross connecting with copper wire, or by motor generators.

(*c*) Reversing the current at frequent intervals.

CONNECTIONS BETWEEN TRACKS AND PIPES:

So long as the trolley is positive the current flowing from the tracks into the pipes does no injury to the pipes; hence all connections between the

track and the pipes are useless, and only tend to raise the potential of the pipes, so that the current will have a greater tendency than before to leave them. The capacity of the return circuit might indeed be increased by connections from the tracks to the pipes, but as this raises the potential of the pipes above the ground, it would result in more injury to the pipes than benefit from the increased capacity of the return circuit.

Connections Between Pipes:

All methods which aim to bring the pipes to a uniform potential by copper wires are useless, because this cannot be done. The copper connections only increase the conductivity of the system as a whole, which would reduce the difference of potential between any two parts, but the potential difference could not, by this means alone, be reduced to zero.

Such methods as using motor generators which should regulate the polarity of the pipes, keeping them as nearly as possible to zero, would be entirely out of the question with so complicated a system as the underground pipes of a large city.

Reversing Current at Intervals:

We have shown by tests at our laboratory that reversing the current at intervals of hours or days is absolutely useless, as the injury to the pipes occurs just the same.

In the foregoing consideration of the schemes proposed as remedies, we have omitted one for the purpose of discussing it more in detail. This scheme is, briefly—to connect the pipes to the negative plate at the power station.

In several cases this scheme has been tried, more or less completely, with beneficial results, and its application to telephone cables is ably described by Mr. I. H. Farnham in his recent article upon this subject. But by this means currents of electricity would be forced to flow through the pipes. Hence, before this remedy can be applied to water pipes, it must first be shown that there will be no injurious action at the joints. This we have discussed before.

If it should prove, however, that injurious action at the joints can be prevented, and if we can show conclusively that the pipes are injured only where they are positive to the ground and are protected from rusting where they are negative, then the object of this remedy becomes evident. It is simply to make the pipes everywhere negative to the ground and to keep them so. To do this the trolley must be positive, which will make the ground in the outlying districts positive, and in the districts where it is shown by hydrant tests that the pipes are positive, copper returns must be run to the negative plate at the power station, until all these pipes have become negative.

If the copper returns from the rails direct to the negative plate be of too low resistance, it is likely to render it difficult to make the hydrants throughout the city negative.

Having once made all the city pipes negative they will have to be constantly watched to see that they remain so; inasmuch as the distribution of the ground currents is likely to change, whenever new lines are run, or the distribution of cars changed.

When it is found in any locality that the pipes have become positive more copper returns must be run from the negative plate at the power station, until these pipes have again become negative.

The original expense for copper returns, together with the expense for constant supervision and for running extra returns when necessary, may be considerable; but it is likely that this will be more than covered by the saving in repairs, should the theory of the protection to the pipes be true.

SUMMARY:

In this discussion we have shown that the existing conditions are suitable for serious injury to the piping system from electrolytic action; and in numerous instances we have positive evidence of this injury. We have connected these conditions beyond question with the return currents of the street railway. Nevertheless, it is absolutely essential in treating this problem to be able to determine from the pipes themselves the difference between electrolytic action and natural corrosion.

We have shown also that when electricity is forced to pass through the pipes trouble from the contamination of the water supply is likely to occur.

We have pointed out that by properly using the ground currents it is possible that they can be utilized to protect the whole piping system from rusting.

With regard to the remedies a word more will be sufficient. Undoubtedly the violent action has been much reduced by several of the schemes which have been tried. But notwithstanding this, long and careful investigation will be necessary in order to determine just how far these remedies are efficient, and what further developments now unlooked for may appear.

## DISCUSSION.

MR. FARNHAM. Mr. President and gentlemen: I came here at the invitation of Mr. Fuller, who knew I was interested in this subject and would probably be glad to listen to the paper, which has been an interesting one to me. It is long and complete, and I hardly feel as though I could add very much to it. There were two or three points suggested, however, which it occurred to me might be made a little clearer, or that might be added to slightly.

Considerable space was given in the opening of the paper to the difficulty of determining whether pipes are exposed to or are undergoing the effects of electrolytic action. This may be true when we take a piece of pipe and examine it, look at it; but, of course, the practical question is, are the pipes in a certain city or in a certain street liable to this action; and I think that the

writer of this paper which you have listened to, although not making it very clear, would agree with me that this is perfectly easy to determine. It is simply a question, as he has in a way pointed out, whether those pipes are electrically positive to the earth or negative. This can be determined readily by a volt meter measurement which any electrician can make.

Now, if one wishes to go further than this in that experiment, he needs only to place by the side of a water pipe, or any other pipe which he mistrusts may be subjected to this danger, another piece of pipe, a short piece, and leave that disconnected entirely from the main pipe. You will see by that means you have there two pieces of pipe, both of them subjected to the same natural causes of decay, and still only one of them is electrically connected to the system of pipes. If, now, the one which is electrically connected to the system shows a greater corrosion, or more deep pits in it than the other piece, it is evidence without dispute that electricity is doing that work.

I suppose that Boston was the first place where this action upon pipes was discovered and proved to be true, and I suppose it was the telephone cables which were first found to be undergoing this danger and damage. This was found early, very early, in the year 1891, and since that time it has been part of my duty to study this subject, which is certainly a very interesting one.

Some of the very first experiments which we made to settle the question were in line with those I have just described. We placed two pipes side by side in a telephone manhole (which is the place in the street where we get at the cables). We placed them upon the ground, connected one of them by means of wire with the cable system, which would allow such currents as would naturally pass from the pipes to the ground to pass through this piece of pipe; the other piece we left disconnected, and in the course of a few days or weeks we examined the two pieces of pipe. The greater corrosion being found upon the pipe which was connected electrically proved without doubt that electricity was the active cause.

Taking Mr. Stone's paper as a whole, I doubt not one would get the fact from it, that electrolysis of pipes could be determined, but in the first part of his paper it seemed to me that he left it a little uncertain as to whether certain pipes were electrolyzed or were simply rusted out from natural causes. I think it is perfectly easy to determine which is operating, and to what extent each cause is operating.

I was interested in that part of the paper which dealt with the poor connections in the water pipe joints. There is no doubt at all as to this fact, that, although the water pipes are put together with a lead ring and caulked quite thoroughly, so the electrician might expect a fairly good electrical joint, there are usually very many very poor joints, so that connecting the pipes to the negative pole of the dynamo in the power station is not sufficient to remove the danger of electrolysis. If the pipes were continuous, so that the pipe became a good electrical conductor, a heavy connection at the power station would ordinarily prevent corrosion. Measurements in Boston and the other

cities prove without any doubt that the joints of pipes have comparatively poor electrical joints, and, therefore, a single connection at the power station is not sufficient.

So far as telephone cables are concerned, we find the method of connecting the cables to the negative pole of the dynamo within the district which is dangerous the most advantageous. It may be interesting to you to point out briefly what I mean by the dangerous district. If the dynamos are operating with the positive side to the trolley line, as ordinarily they are, naturally there is a district near the power stations, sometimes 1,000 feet in extent and sometimes a mile (in Albany we found this district extended a mile in one direction from the power station), in which the disposition of the current is to leave the pipes through the earth and get again to the dynamo through the rails. This is the "danger district." Now, this territory can be mapped out in any city by volt meter measurements, and within this district we have found that a large return wire connected to the dynamo is sufficient to bring all the cables to a zero potential or below zero; that is, they will become negative to the earth instead of positive, in which condition the current flows on to them instead of flowing off, and the danger of electrolysis is removed by that means. There is no danger where the current flows onto the pipes.

I have more faith in that remedy, just described, when applied to water pipes than the writer of the paper has expressed. The difference of potential between two sections of pipe outside of this "danger district," as is found by measurements, is extremely small. If now within the danger district the copper wires are laid to points all through that district and connected frequently, we will say at every hydrant, it is my belief from the work we have done, that the danger to the pipes will practically be removed. But, as Mr. Stone has pointed out, it must be watched continually, for changes in the power or in the handling of the cars will change this danger district. (Applause).

MR. COOK. I would like to ask Mr. Farnham if he considers that the danger district would be nearer the power station with the trolley wire positive than with the rail positive.

MR. FARNHAM. With the positive side of the dynamo to the trolley wire the danger district will be at the power station and near it.

MR. COOK. And with the rail positive it will be at the extremities of the line.

MR. FARNHAM The opposite would be true; the safe district would be near the power station, and the outside district would be the danger district, and in that case the danger district would be very much larger in area.

MR. COOK. Then the safest way is to have the trolley positive?

MR. FARNHAM. I think so, for two reasons: It gives you an opportunity to handle the trouble by a large return wire to the station; that is my first reason. The second is, it would seem to me much better to confine dangerous action to a small territory, even though the local damage be more rapid in that

territory, than it is to have it slowly going on over most of the city. Take Boston, for instance, as an illustration of that. At the Albany Street power house, the danger district extends out about 2,000 feet in each direction, in three directions we will say, making the power house the center. All of the rest of the city, today, except those districts which lie near the East Cambridge power station and the Allston power station, are free from any danger. Now, if you reverse the current, which has been done in Boston (so we know by tests and not by theory), the safe district is only this small district of about 4,000 feet in diameter, while the city at large is the "danger district."

MR. COOK. Why I asked the question was, that in my city the positive current goes to the rail. I have been unable to find any trace of the current near the power station, but I have found it at the outside limits, that is, within 500 or 1,000 feet of the terminus of the railroad track.

MR. FARNHAM. That is exactly correct. The railroad in this city was operated in that manner when this corrosion was first discovered, and in order to remedy it, or to make the remedy more easy, a reversal was made. But in most cities the railroads have always operated with the positive side to the trolley; there are a few exceptions.

MR. FULLER. I would like to ask Mr. Farnham whether, if some other material than lead was used in making the joints, something that is a better conductor of electricity, there would be any less danger?

MR. FARNHAM. Mr. Stone in his paper has suggested something in this line. I think unquestionably if the single trolley is to be used, and the currents return to the earth as at present, it would be an advantage to connect the sections of pipe thoroughly electrically; that is, to make a joint that is electrically good, which could be done by a heavy copper bond, or by any other thoroughly metallic connection. The pipes as they are laid now are usually covered with paint, asphalt, and then this ring is put in, which is not a good metallic connection. If they can be connected metallically by a large surface, then the danger to the joints will be removed and the remedy can be applied at the power station much more certainly than at present.

MR. H. C. FORBES. I think it might be interesting in this connection to say a few words. The West End Road have adopted the method of running their trolley positive, and have made a connection from the pipes to the negative plate of the dynamo. That is the way I understand it. Well, now, in spite of this, on account of the complicated system of piping, we find, as Mr. Farnham says, that in the danger districts the hydrants are positive; but we also find positive hydrants scattered all over the city, due, undoubtedly, to points at which the pipe is somewhat disconnected. So I do not think the rule will obtain so definitely when the piping system is as complicated as it is here.

MR. WINSLOW. There is one fact which has been mentioned, and that is that the current does a great deal of damage to the pipes which must be repaired by the corporation or municipalities in charge of the works, whether gas or

water, and the railroad companies are getting the benefit of it. Now, it seems to me that as soon as possible the companies should be prevented from doing the mischief. Under the present conditions it does not seem to be possible to stop it practically. But according to the paper which has been read, there are two ways of partially, if not wholly, preventing the current from entering the earth at all. One is, the double trolley and the other is the storage battery system.

Now, with the present trolley system the current goes out, at least I will assume it goes out, on the trolley, goes through the car to the ground and thence back to the station. The return wires and rails are supposed to take the most of the current, but they evidently do not. Now the resistance of the rail and of the return wire is very slight indeed, and the resistance of the earth is considerable, but still enough of the current will leave the rail and wire and go through the earth and take to the water pipes to destroy the pipes. My idea in regard to that would be to stop it altogether if possible.

I can see no reason why a double trolley system would not operate the same as on the ordinary metallic lines for telegraph instruments or fire alarm systems, with which I have had a little more experience. Now, on fire alarm work, let the limb of a tree, which has considerable resistance, touch a wire, and some of the current will be deflected and return to the earth. So it appears to me that the double trolley system will not entirely prevent the current entering the ground and injuring the pipes.

It appears to me that the best system so far as the prevention of injury to the pipes is concerned is the storage battery system where the current is given and received and has no distance to travel, from the generating point back to the place where it is generated. It is said that the storage system has not yet arrived at that state of perfection which will enable it to be used with any economy. And here we reach the very point which I desire to make. If it is more economical to run the cars by the single trolley system then let the railroad companies pay the cost of damage to the pipe systems. When the cars are run by the storage system, the current simply passes from one wheel to the other, or across the track, and is thus confined in a very limited space, while with any other system it has a chance to travel the length of the line, whatever it may be.

Mr. Thomas. There have been electric cars running in Lowell since 1889, and I have never yet known a case of electrolysis of a water pipe, and I haven't heard of any effect on the gas mains. We have here with us as a representative of the Lowell Water Board a man who has been connected with the electric railway in Lowell, and he probably can throw some light on how they are able to manage there so that our water pipes have not been affected by electricity. I will call on Mr. Fell.

Mr. Fell. The electric road has been in operation in Lowell since 1889. About five miles of the road was built at about the the same time they started in Boston. Our ground wire was very small at first, and we found the difficulties which have been mentioned here. Today 45 miles of electric road are in use in the city of Lowell. About three years ago heavier return wires were

put in and we also have a connection every 1,000 or 2,000 feet to an overhead wire, by which we return our current to the station. At some points, in the center of the city, the cars are run every half minute, or oftener. Of course the street is full of water and other pipes, but we have never experienced any difficulty, although, of course, I have read of the trouble in Boston and other cities, notably in Minneapolis, where the road is a comparatively new one, built two or three years ago. As I am connected with the water works I would have been very likely to have heard if any trouble existed. I have met Mr. Farnham in Lowell, and we have discussed the double trolley system and the single trolley system. I have considered that the nearest we want to come to a double trolley system is to have an overhead return conductor, and we have found that this not only carries the current better, but assists us in our power, at least that is what our engineers report. I am not practical enough to go into any argument about it. I can simply say, being a member of the Water Board of the City of Lowell, that as far as the Water Board is concerned, or any corporation in the city which is running pipes in the ground, I know of no cause for a complaint against the railroad company in our city.

MR. FULLER. I would like to ask Mr. Farnham if there is some easy and practical way by which the Superintendent of a Water Department can tell whether his pipes are in any danger, and also whether in his opinion it would be wise to institute some examinations from time to time in regard to whether the pipes are being affected by the electric current?

MR. FARNHAM. Mr. President: If I am not taking time which does not belong to me, I will say that I think it is entirely practicable. As Mr. Stone and others have pointed out, it is only necessary to know whether the pipes are electrically positive to the earth or negative. If they are positive, the current is passing from them to the ground. If the current is passing from them to the ground, then electrolysis is going on. Of course, you may find a place like Lowell, or any other city, in which the pipes have not yet been eaten through, but is certainly no evidence that the action is not going on. A voltage measurement, which it is a very simple thing to take, made between the hydrant and the moist earth, or better still, between the pipes themselves, and the moist earth surrounding them (excavating the earth where you wish to make the examination), will show you at once whether they are in a dangerous condition or not. It has been proved that a very small amount of current, that is a very small difference of pressure between the pipe and the ground, is sufficient to cause the action—not so rapidly as if the difference was greater, but any difference of potential will cause the action. If your pipes are positive to the ground, they are certainly being corroded; if they are negative to the ground, they are certainly not being corroded by electricity.

MR. COOK. I would like to have Mr. Farnham explain how to test by a galvanometer, and to tell by the way the needle will follow whether the current is positive or negative.

MR. FARNHAM. A volt meter is the simplest instrument to use; it is one form of a galvanometer. (Mr. Farnham illustrates his remarks by a sketch

upon the blackboard showing a simple galvanometer or volt meter.) Unless there is considerable current flowing a simple galvanometer will hardly give motion enough for you to be certain of its movements. For your purposes a "Weston Volt Meter" is desirable.

MR. WINSLOW. I would like to ask in regard to that simplest form of galvanometer which you speak of; whether you pass a coil of wire or simply a straight wire under the compass?

MR. FARNHAM. Simply a straight wire. If we wish to increase the sensitiveness of the needle, we will wind the wire right around the instrument as many times as we please, and then carry it on. The simplest form is simply passing it under straight. It is perfectly easy to make these measurements, and if you feel uneasy about your pipes you had better make the test; if you find they are negative to the ground or wherever they are negative, they are perfectly safe; if they are positive they are in danger.

MR. CHASE. There is one point which has not been touched upon in this discussion, and that is, after we discover that the damage is actually being done, what are we going to do about it? Assuming a case where the water works are owned by a private corporation, that question is particularly pertinent. If the municipality owns them it, perhaps, has the power to say to the electric company that it must do something to remedy the damage. Where a private corporation, however, is the injured party, and it has been given certain rights in the streets, given permission to lay its pipes, and later on this new innovation has been given rights, the municipality may perhaps consider that the two corporations have a private quarrel and leave them settle it between themselves. Now, if some way can be devised by which this malicious element can be turned back upon the prepetrators of the mischief, and make them pay the penalty in that way I think we would all be fully as much interested in that as in finding out that the mischief is actually being done. I wish our friend, who has interested us so much already, would be able to throw a little light upon the solution of that problem.

MR. ALLIS. I think it has been stated within a short time in one of the engineering journals, that several applications for the use of an electric franchise have been refused the companies on the very ground that they would not agree to protect the water pipes from this danger which we have heard described in such an interesting way today. I have also seen the statement that in England and in Scotland that policy has been adopted, and the companies there are compelled to agree to take care of their electricity so that the pipes of the city shall not be damaged.

MR. SPARKS. I am Superintendent of the Water Department of a company in Brewer Maine, which has a power station in the town of Veazie, situated 4 miles above the city of Brewer. The company operates the Bangor and Brewer Street Railways, and also an electric light plant, and the pumping station and power plant are in the same building, the entire plant being run by water power. To conduct our water to the city of Brewer we were obliged to cross the Penobscot River with a 12-inch main. The main was laid across from the

Veazie Station to Brewer in 1890, and for conducting the return current, the same company owning the water plant and the electric plant, the return wires were connected to the hydrants all along the line of pipe, a distance of about 7 miles. In two or three months after the electric current was turned on the pipe burst in the river in 35 feet of water. In a very short time after the damage was repaired the pipe again burst. The Ward joint had been used in putting the pipe across the river, and none of the joints gave out. In perhaps six months there was another break, not in the joint, but in the pipe itself. These breaks were not in the form of a regular split, as we sometimes have on the land, but they were irregular. In some instances the pipe would break for a distance of perhaps 5 feet, and the break would run nearly around the pipe, there seeming to be no regularity to it.

My company did not think the electric current could possibly be responsible, although I insisted that it was. Finally, the current was carried across the river by means of seven strands of No. 6 copper wire, connected with the pipes on either shore. The old main had been entirely destroyed, and a new one was laid across the river, and since doing that and making the connection as described, I have had no trouble. The original 12-inch main was so affected that in one instance by striking three blows with a striking hammer on a pipe which weighed 100 pounds per foot, a hole was broken through it, without cracking the pipe in any other place. By simply pounding on the pipe pieces as large as the face of the hammer could be broken out, and the pipe cut clear off in that manner without cracking it anywhere else. That length of pipe resembled black lead as much as anything else. At another place where the line crosses a little stream very near the river, seven or eight lengths of pipe have broken in the same manner as the pipe in the river. I finally put wire on to that and carried the current across the stream, and have had no further difficulty there. The trouble seems to have been where the electric current has left the main pipe in the water. Our power station being about two miles above the river crossing, the current has seemed to leave the pipe there and gone to the power station by way of the river.

MR. COOK. I would like to ask if the break went exactly around the pipe without any pitting at all?

MR. SPARKS. The pipe was also pitted somewhat, but the crack did not go entirely around the pipe. It ran in a jagged way like chain lightning, that is it was very irregular.

## THE FILTER OF THE WATER SUPPLY OF THE CITY OF LAWRENCE, AND ITS RESULTS.

BY

HIRAM F. MILLS, A. M., C. E.,

Member of the Massachusetts State Board of Health.

[Read June 14th, 1894.]

The Lawrence Pumping Station is by the side of the Merrimack River, above the city and about 1,000 feet up stream from the nearest house. The water was drawn from the river through a 30-inch iron pipe, continued to the engine house by a brick conduit 4 feet in diameter. At right angles with this conduit and extending down stream from the engine house, for 300 feet along the shore, was a stone and brick filter gallery, 8 feet wide and 8 feet high inside, the bottom of which, as well as the bottom of the conduit from the river, was about level with the bottom of the pump well under the engine house and 11 feet below low water in the river.

The river water brought so much silt at the time of spring and fall freshets, that the shore became impermeable, and soon after the works were constructed it became evident that the filter gallery received little or no water from the river side, and the quantity received from the land side was insignificant. The works have been in use about 17 years. For some years after they were built there was a diminution in the number of deaths by typhoid fever from the number when well water was used, and no one thought of direct poisoning by sewage of the water taken from the river 9 miles below Lowell with a fall of 10 feet through a rapid a mile long on the way. Many made the remark that running water purified itself in a less distance and put away any fear of contamination, while a few did not like to drink water into which the sewage of 70,000 people was poured only 8 hours before it reached the intake of the water works.

Shortly after the State Board of Health was reorganized in 1886, the Experiment Station was established at Lawrence, and it was soon found that all of the bacteria in sewage, amounting generally to several hundred thousand in every thimbleful, could be removed by slow intermittent filtration; also, that the same result could be attained by filtering water at a more rapid rate, but not at a rate that rendered it practicable to apply to a city's water supply. Experiments of the Board with rapid mechanical filters showed a large percentage of the bacteria remaining in the filtered water, and experiments at Berlin indicated that the continuous filters of that city allowed some of the germs of typhoid fever to pass through; enough to cause sickness in the city.

In 1890, a careful study of the deaths from typhoid fever in the cities of the State showed that the cities of Lowell and Lawrence had nearly three times the average number, from the same population, in other cities; and that during the season—August, September and October—when other cities had

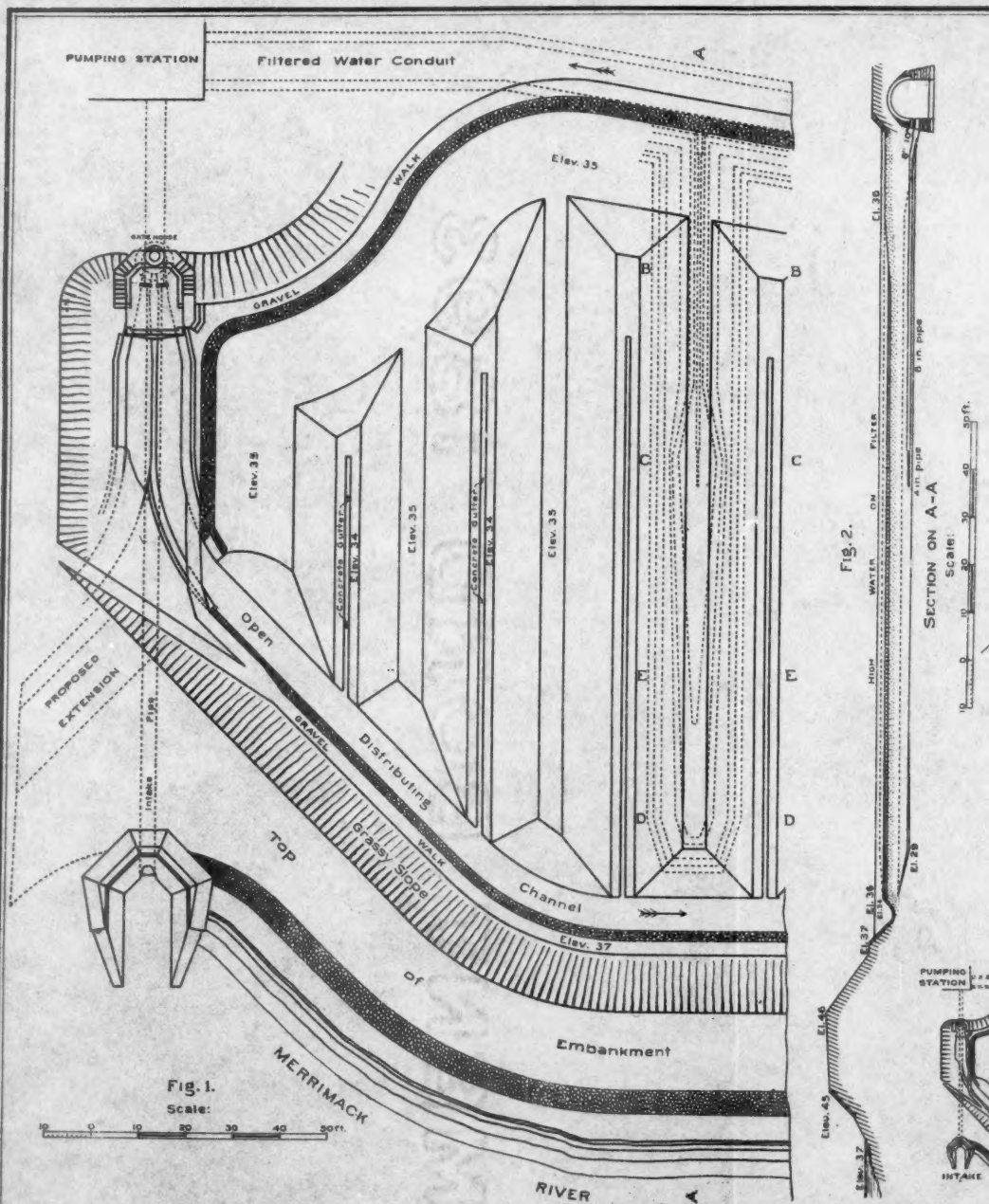
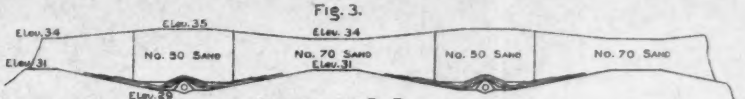
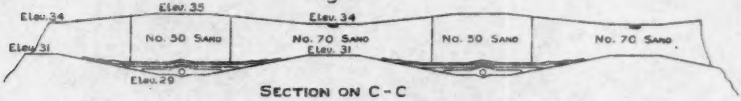

PUMPING STATION
Filtered Water Conduit
A
WALK
GRAVEL
Elev. 35
GATE HOUSE
B
C
D
E
Elev. 35
Concrete Gutter
Elev. 34
Elev. 35
Concrete Gutter
Elev. 34
Elev. 35
Open
PROPOSED EXTENSION
Pipes
Intake
GRAVEL
Distributing
WALK
Grassy Slope
Top
of
Embankment
Channel
Elev. 37
MERRIMACK
RIVER
Fig. 1.
Scale:
10 0 10 20 30 40 50ft.
Fig. 2.
SECTION ON A-A
El. 38
8 in. Pipe
FILTER
WATER ON
HIGH
4 in. Pipe
El. 38
El. 37
El. 37
El. 46
Elev. 45
Elev. 37
Scale:
10 0 10 20 30 40 50ft.
PUMPING STATION
INTAKE

Fig. 3.




Section on B-B

Fig. 4.




Section on C-C

Scale:

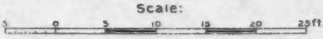
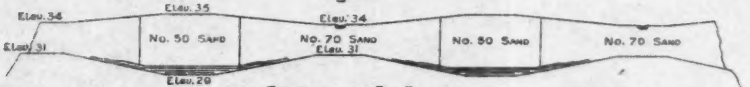
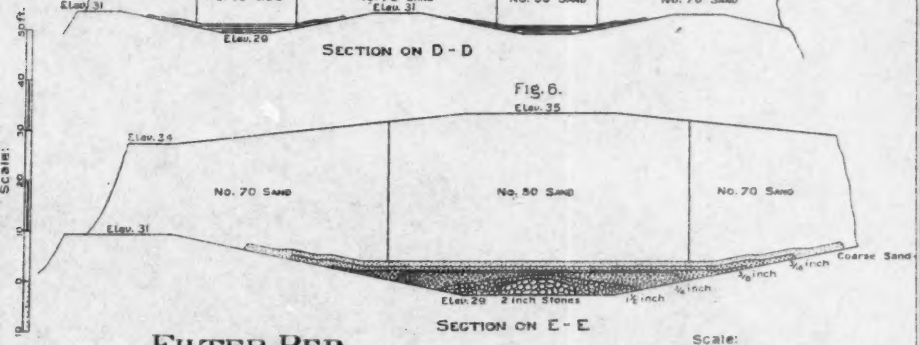



Fig. 5.



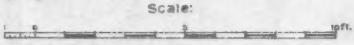

Section on D-D

Fig. 6.




Section on E-E

Scale:




# Filter Bed
## of the
# City of Lawrence, Mass.

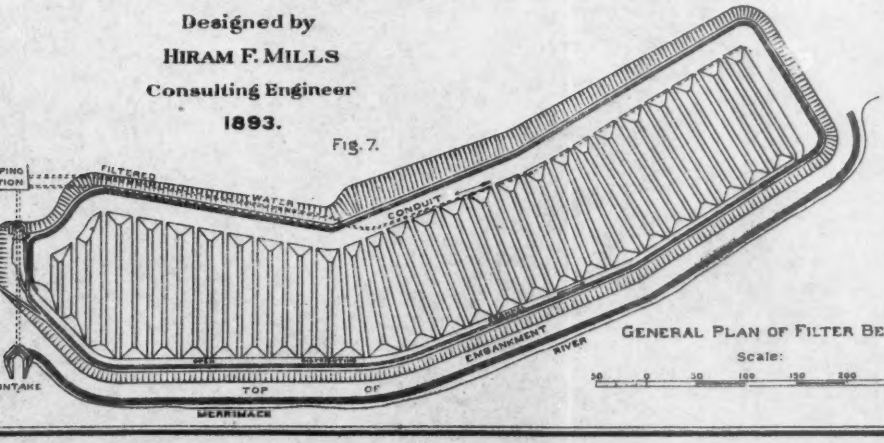
**Designed by**

**Hiram F. Mills**

**Consulting Engineer**

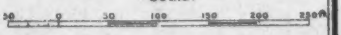
**1893.**

Fig. 7.




General Plan of Filter Bed

Scale:



the most typhoid fever, Lowell and Lawrence had about the same number as other cities, but a month or more later the deaths in Lowell reached three and four and eight times the deaths in other cities, and after another month those of Lawrence increased by a still greater ratio, so that in some years the deaths in January and February from this disease were more than the actual number in Boston, with 10 times the population. This condition, following year after year, made it so evident that the disease came down the river to Lowell from the cities and towns above, and then came with greater intensity from Lowell to Lawrence, that the State Board of Health made strenuous efforts to produce a filter that would remove all disease-producing germs that could be applied to it, and at the same time to filter rapidly enough to serve for a city's water supply. Billions of typhoid fever germs were cultivated and applied to filters of different construction, and in 1891 we succeeded in removing all that were applied when filtering 2,000,000 gallons per acre daily. Then the Board advised the City of Lawrence to filter its water, and offered to show how to do it.

Such a filter would require some layers of quite fine sand, and it was thought necessary to first take out the very fine river silt from the water by means of a coarser sand filter at the river bank. Further experiments showed that the construction of a filter at the river bank with a sand coarse enough to allow the river silt to be deposited upon it, if removed promptly, would serve to remove 98 per cent. of all the bacteria of the river water and a still larger per cent. of the disease-producing germs, and considerations of economy and the immense advantage of such a filter with the probability of this or none, with an unbelieving public, induced the State Board of Health to advise the city to immediately construct such a filter and save the 57 lives, which was the annual excess of deaths by this disease over that of the same number of inhabitants in cities of the State having a good water supply.

In 1892, in view of the possibility of cholera getting into Lowell and making it necessary to cut off the Lawrence water supply, the City Government made an appropriation for beginning the work of constructing the filter in accordance with the advice of the State Board of Health and under its direction.

The general design was to excavate the bed and bank of the river to 7 feet below low water, for a width of about 150 feet out from the old filter gallery and from the high water shore down stream from this, making a length of about 750 feet and an area of excavation of 2½ acres. The suitable material from the excavation was to be put into a tight embankment, on the ends and river side, carried to 9 feet above low water in the river or high enough to exclude the highest freshets. The excavation was to be then filled for a depth of about 5 feet with suitable filtering sand properly underdrained into the old filter gallery and into a small perforated conduit in extension of the gallery.

The top of the sand, being 2 feet below low water in the river, could by a proper inlet be flooded by gravity to a depth of about 2 feet, thus forming a shallow pond of 2½ acres area, which would gradually filter downward through the sand to the underdrains and be conveyed to the old gallery, and through this to the pump well.

One of the essential qualities of the design required that the inlet water should be shut off once a day and the pumps kept running until the sand was uncovered and the water within the sand drawn out so that the sand could fill with air from top to bottom.

This condition of filling the sand with air daily was regarded necessary to insure the burning up of the organic matter which penetrated the sand below the surface and forming nitrates in the water, thus producing conditions the most unfavorable for the continuation of the life of bacteria within the water in their passage through the sand and in the water after leaving the filter.

There is nearly air enough in our drinking waters to supply the oxygen which is necessary to carry on the process of nitrification when the water comes in contact with the grains of sand which have nitrifying bacteria adherent, but the addition of the air which enters the sand by drawing the water out of it once a day causes a more complete burning up of the organic matter in the water, which is the nitrifying process spoken of.

The question may arise, if water contains so much air why does not nitrification take place in a reservoir? The reason is that nitrification will not take place unless the water with the air comes in contact with certain bacteria, which in some unknown way cause the process to be carried on. These bacteria attach themselves to the grains of sand of the filter and remain there, and when air is present they can in a short time cause the nitrifying process to be carried on so completely that nearly all of the organic matter in the water is burnt up, and with this burning the disease germs in the water are killed.

The carrying out of this design required some original investigations upon the head required to convey a definite quantity of water through sands of different size of grain and through gravel stones of different sizes. The circumstances of the location would allow an expenditure of head of $1\frac{1}{2}$ feet when the surface of the sand was clean, through the sand and through the underdrains and conduit to the pump well, when drawing the full quantity of 2,000,000 gallons per acre per day, or 5,000,000 gallons for the field.

The sand selected to meet these conditions was of two sizes, the finer of the two being placed directly over the underdrains and for 5 feet each side of them; and the coarser occupying the remaining 20 feet between the drains, and through which the water would move laterally and use up about the same amount of head as when flowing directly downward through the finer sand.

The coarser sand was such that 70,000,000 gallons would flow in 24 hours through a foot in depth, covering an acre, with the expenditure of one foot head; and the finer sand would convey 50,000,000 gallons under the same conditions. In moving vertically downward 5 feet through the finer sand, 10,000,000 gallons would flow through with the expenditure of one foot of head, but the water moving laterally through the coarser sand toward the underdrain would crowd the stream in the finer sand below the surface so that the water going through the surface in a width of 10 feet would be, near the bottom,

pressed into a channel of perhaps not more than 5 feet in width, and thus decreasing the quantity that could pass with 1 foot head to perhaps 7,000,000 gallons per acre per day.

As the water was to flow through the sand with a daily intermission of several hours, the actual time of flowing would be, say two-thirds of the day, and would allow between 4,000,000 and 5,000,000 to pass. This is the quantity that could pass with 1 foot loss of head through the sand when the surface of the sand is clean, but the fine mineral sediment and the organic matter brought by the river water choke the surface and reduce the quantity of water that can pass through, and in order not to have to clean the surface too frequently, the sand, when clean, should be able to convey two or three times the quantity required.

It was expected, from experiments that had been made with this water, that ordinarily, with sand grains of the size here used, the surface would have to be cleaned by removing from an eighth to a quarter af an inch and replacing with clean sand once a month, and that during freshets, when more sediment comes in the river water, the surface would have to be cleaned oftener.

If the surface should not be cleaned as often as necessary, the result would be a lowering of water in the pump well, and if neglected until the surface becomes so impervious that the one or two feet in depth of water over the surface were not sufficient to force the required quantity through the upper layer, the drawing down of the pump well to the bottom of the sand would give no relief; the surface would have to be cleaned.

Economy of construction, the providing for a nearly uniform rate of filtration through every square foot of the area of the filter, and applying the water to the surface of the sand in a valley, so that, as it is filled daily, there will not be a current over the surface of the sand sufficiently rapid to move the sand grains, caused the following section to be adopted :

The underdrains were arranged to be 30 feet apart. The excavation was not made to a uniform depth of 7 feet below low water in the river, but was made to the depth of 8 feet for a width of 5 feet where the underdrains were to be, and to the depth of 6 feet for a width of 5 feet at ridges between the underdrains, with slopes of 1 foot in 10 feet between. Over these ridges the sand was filled only to the depth of 3 feet for a width of 5 feet, and beyond this the surface of the sand rose 1 foot in 20 feet and then ran level for 5 feet at a height of 6 feet above the bottom. Such ridges and hollows formed the general longitudinal section of the bed.

The direct conduit through which water was formerly supplied to the pump well from the river is at the up-river end of the filter bed. It is furnished with a gate at the inner end, and the top was pierced and a chimney built about 40 feet outside of the engine house, and projecting through the side of this chimney were set two iron pipes 2 feet in diameter with a gate in each, having its center 2 feet below low water in the river. One of these is intended to supply an extension of the works up the river ; the other discharges into an open conduit which extends along the inside of the embankment nearly the whole length of the bed. At the upper end the section is a semi-circle 6 feet in diameter. The

edge toward the bed remains level throughout its length at 3 feet below low water of the river, but the bottom rises gradually from 3 feet below the edge to 6 inches below at the lower end, and this continues by a curve and crosses the bed in the down-river valley with the edges level, but the bottom rises so that the depth at the end is only 1 inch. In each of the valleys, 30 feet apart, extends from this main conduit, a shallow carrier of concrete lined with cement mortar, having its edges level with the edge of the conduit, and extending from the conduit to 32 feet from the opposite side of the bed. These are 2 feet wide and 3 inches deep at the conduit, and 1 foot wide and 1 inch deep at the end. In this way there are formed edges of water carriers at the same level and about 1 1-3 miles in length, over which the water reaches the sand, and as within 2 feet from these edges the surface of the sand rises with a slope 1 foot in 10 there is very little perceptible current over the sand as the water leaves the carriers.

The conduit is made of cobble paving stones 4 to 6 inches through, laid in Portland cement mortar on a layer of gravel 8 inches thick and made smooth within by a coat of mortar. The carriers are made of cobble stones about 4 inches in diameter, laid in Portland cement mortar on the sand, and made smooth within. At the junction with the conduit the carriers are widened by curves to prevent washing of sand at the turn.

The underdrains enter the old filter-gallery through holes cut in the wall. Glazed sewer pipe surrounded by stones are used for about four-tenths of the distance from the gallery across the bed, beyond which are layers of stones of different sizes without pipes. Beginning at the gallery is one length of 10-inch pipe, then two lengths of 8-inch pipe, then from 35 to 65 feet of 6-inch pipe, ending with three lengths of 4-inch pipe. These pipes are laid apart so that the spigot approaches but does not enter the bell, and they are surrounded by a layer of about 4 inches of stones about 2 inches in diameter. Other layers, deceasing in size through 1½ inches, 3-4 inch, 3-8 inch and 3-16 inch, are applied in the form shown by the sections and plans, and the latter being spread out to a width of 17 feet is covered by 1 inch of coarse mortar sand which spreads to a width of 20 feet. Upon this rests the filtering sand from 4 to 5 feet deep.

The valley in the excavation is deepened in the part occupied by the pipe so that the pipe has a slope of 1 foot in 100 feet. The pipe was applied as far from the filter gallery, or conduit in extension of the gallery, as it and the stones surrounding it cost less than the much larger area of stones required to give the desired freedom of flow. Beyond this the large stones were spread out to the widths and with the depths required to give the desired flow.

To determine how much head would be used in flowing through layers of sand and layers of stones of different sizes experiments were made under my direction by Mr. Allen Hazen, the chemist in charge of the Experiment Station of the State Board of Health. As is well known, the head required to convey water through ordinary pipes varies with the square of the velocity, but with extremely small pipes and through the interstices of fine sand the head required to convey water varies with the velocity and with the temperature,

more head being required with colder water. Through coarse sand and through gravel stones the head varies with powers of the velocity between the first and second powers, increasing with the size of the grains or of the stones. For sands, 10 per cent. of whose grains are as small as 2 millimeters or 8-100ths of an inch in diameter, the quantities of water that would pass through an acre in area with different depths and sizes of grains were determined by the following formula deduced from experiments which had been made up to the time of constructing this filter: $Q=\frac{800hd^2}{l}$ in which Q expresses the quantity of water in million gallons per acre per day, $h$ the acting head in feet, $l$ the distance flowing through the sand in feet, and $d$ the maximum diameter in millimeters of the finer 10 per cent. of the sand grains.

This formula expresses quite satisfactorily the quantity of water that will pass through clean sand, from which air has been pushed out, when the temperature is about 50 degrees Fah., and is convenient to use in comparing sands of different sizes ; but Mr. Hazen found that the resistance was nearly twice as great when the temperature was near the freezing point as when at summer heat, and he afterward determined an expression, from the experiments, giving the velocity of flow through sands at any temperature, which may be found on page 553 of the Report of the State Board of Health for 1892.

The sand used in the Lawrence filter, which was placed directly over the underdrains and 5 feet on either side, had the coarser grains of the finer 10 per cent., 25-100ths of a millimeter in diameter, and by the above formula when the head used is equal to the distance which the water passes through the sand the quantity of water that could pass through an acre in 24 hours would be 50,000,000 gallons. If 2,000,000 gallons were applied to an acre in 16 hours, or the equivalent of 3,000,000 gallons in 24 hours, and this were crowded into one-half its area near the bottom of the sand, by the lateral pressure of the water coming towards the underdrains through the 10 feet of coarser sand on each side, the resistance would be like that of 4,500,000 gallons traversing 6 feet in depth of sand, for which the head required would be 54-100 of a foot.

As the circumstances here allowed of a loss of head through the sand of 1 foot, the remaining head from 54-100 to 1 foot was the amount allowed for increased obstruction through the sand due to air and to lower temperature.

By a similar process of computation the coarser sand occupying the remaining 20 feet of the 30 feet between underdrains was found to be able to convey its proportion of the water to the underdrains with a like loss of head ; hence, the arrangement presented by these sections enabled all parts of the area of the filter to transmit nearly their proper quantity of water.

With this loss of head through the sand when clean, there would be a noticeable increase in loss by a slight deposit of sediment upon the surface, and depending upon this narrow margin it was deemed practicable to construct and use for a term of years a single bed, which was to be cleaned regularly each month, a portion being cleaned every day during the interval when the bed is resting ; and this portion when cleaned is not capable of conveying so large a quantity of water that it cannot be properly purified in its passage, unless there be an extreme drawing down of the head which would require very close watching at the pumps.

When it becomes impracticable to properly purify the full amount of the city's supply by the present bed it is designed to construct another bed extending up the river from the intake, to be supplied by the second 2-foot valve mentioned as built into the side of the chimney rising from the old intake.

We have followed the water through the sand and considered the head lost in its passage. There is still some head to be used in passing through the layers of stone and the underdraining pipes.

In considering the loss of head through fine sand and through coarser material to the very large gravel stones, we find the loss increasing with the first power of velocity, and with powers increasing with the coarseness from the first to the second power of the velocity, hence the most convenient method of presenting what our experiments have shown is in the form of a table which was used in distributing the remaining allowable loss of head of about half a foot in addition to the 1 foot through the sand, so that it should still serve to make the passage of water nearly uniform from all portions of the surface of the bed.

This table, though capable of improvement by additional data, led to conclusions which proved satisfactory in this case.

QUANTITY OF WATER FLOWING THROUGH GRAVEL STONES AT DIFFERENT HEADS.

| Loss of head in terms of distance through gravel. | Size of gravel stones in millimeters and inches. The finest 10 per cent. finer than— | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Millimeters.. | 3 | 5 | 8 | 10 | 20 | 30 | 40 | 50 |
| | Inches..... | 0.12 | 0.20 | 0.32 | 0.39 | 0.79 | 1.2 | 1.6 | 2.0 |
| | Quantity flowing in 1,000,000 gallons per acre daily. | | | | | | | | |
| 0.0005 | ..... | 4 | 12 | 22 | 35 | 90 | 170 | 280 | 410 |
| 0.001 | ..... | 7 | 23 | 43 | 65 | 160 | 300 | 480 | 690 |
| 0.002 | ..... | 15 | 43 | 84 | 120 | 300 | 490 | 720 | 1,040 |
| 0.004 | ..... | 29 | 83 | 160 | 230 | 520 | 790 | 1,070 | 1,360 |
| 0.01 | ..... | 72 | 185 | 320 | 420 | 890 | 1,280 | 1,670 | 2,150 |
| 0.02 | ..... | 136 | 320 | 500 | 630 | 1,280 | 1,800 | 2,340 | 3,030 |
| 0.05 | ..... | 300 | 600 | 950 | 1,140 | 2,030 | 2,862 | 3,734 | 4,800 |
| 0.10 | ..... | 530 | 1,000 | 1,400 | 1,650 | 2,850 | 4,044 | 5,280 | 6,800 |

By the aid of this table the underdrains, formed of layers of stones of different sizes were proportioned as shown in the accompanying plan and sections. The larger stones were selected by hand, and if soiled were washed. The smaller sizes, were selected by screening, and in this way all sand was removed. The stones of the two larger sizes were carefully placed at the open joints of the pipes to allow water to enter as freely as possible, the other layers were shovelled to place.

In extension of the old filter-gallery, to serve to conduct the water from the down river underdrains to the gallery, a conduit was built with walls 4 inches thick of brick laid in Portland cement mortar, with the mortar left out of the end joints, which were a little more than $\frac{1}{8}$ of an inch wide. This conduit was 2

feet in diameter for a length of 105 feet, then 20 inches in diameter for a length of 120 feet, then 16 inches in diameter for a length of 65 feet, then 12 inches in diameter for a length of 30 feet, beyond which were 10-inch, 8-inch and 6-inch glazed pipes, in lengths of 30 feet, laid as in the underdrains. This conduit was surrounded by the large stones, 2 inches in diameter, for a thickness of 4 inches, with layers of decreasing sizes around this, making a total thickness of about 8 inches.

Great care was taken to deposit the filtering sand so that the mass should be as homogeneous as possible. It was deposited in two layers. The first layer was covered with planks as fast as laid, upon which the loads were hauled, and these were dumped upon the planks near the edge, so that a part of the load ran over the bank and the other part was shoveled over. If the edge of the bank remained exposed to the wind and sun the coarser material would appear on the surface and run down. Such an edge was shovelled over before an addition was made.

The second layer was dumped upon the planks resting upon the lower layer and shovelled up to grade, and upon taking up the planks the lower layer was shovelled over to the depth of 1½ feet to remove the packing of the sand which was evident under the planks, sometimes to a depth of 1 foot.

It will be evident that watchful care was necessary in laying the underdraining stones to see that no bar of finer material crossed it in any direction. In fact, the success of the filter depended largely upon careful and conscientious superintendence of the construction of the underdrains and the bed. This was accomplished by Mr. Charles C. Campbell, who had an intelligent appreciation of the essentials to success and most scrupulous care that the work should be done as directed.

Sand for the filter was obtained from a bank about seven-eighths of a mile away, where layers and pockets were found containing all kinds, from the very fine, almost impervious sands to large gravel stones, and much unsuitable material had to be removed in selecting layers from which suitable sand could be obtained. By judicious selection, screening and mixing, the two kinds of sand were obtained and wheeled to piles for loading. These piles were frequently tested by half filling with sand a cylinder 6 inches high and 3 inches in diameter, having a wire bottom. The sand was packed slightly and covered with a wire screen and the cylinder filled with water, and the time observed that it took the water to pass below the surface of the sand. Time limits for the two grades were determined at the laboratory, making correction for the temperature of the water, and the accuracy of these tests at the bank was determined by occasionally taking duplicate samples to the laboratory and making regular mechanical analysis by means of sieves.

The filter was completed, at a cost of about $65,000, in the forenoon of September 20, 1893, just about one year from the time of commencing, although there were four or five months when work was suspended; and in the afternoon of September 20 the inlet gate was opened and the water filled the open conduit along the base of the embankment, ran into the carriers, and gradually flowed over the 1½ miles of level edge and entered the sand, disappearing in a short

distance at first, but gradually, as the sand was filled, extending further from the carriers and filling the bottom of the 26 valleys, and then rising slowly up their sides and covering the ridges, forming a shallow pond of 2½ acres. Then the pumps were started and when running at the rate of 5,000,000 gallons in 24 hours we found that the difference in level between the water over the filter and in the pump well was 17 inches.

The water first coming through the filter contained an extremely fine dust in suspension, probably washed from the surfaces of the stones and underdrains. In the first 10 days the chemical changes in the water were as follows: The albuminoid ammonia was reduced from 0.0168 to 0.0108 in parts per 100,000. The free ammonia was reduced from 0.0113 to 0.0072, and the nitrates were increased from 0.012 to 0.020 parts. The color was reduced from 0.36 to 0.28 on the scale for color. Since that time the average change has been in albuminoid ammonia from 0.0187 to 0.0104; free ammonia, from 0.0067 to 0.0087, and the nitrates, from 0.014 to 0.039 parts, and the color reduced from 0.42 to 0.35. The hardness of the water has increased from 1.3 to 2.9. This change is probably partly temporary, due to absorption of lime from the conduit and carriers, but it is partly due to ground water, as it was the greatest when, in the latter part of February and early part of March, there was the greatest loss of head through the filter, and consequently the greatest draft from the ground. At the same time, there was an increase in the free ammonia of the filtered water, evidently due to the same cause; but this cause was an exceptional condition due to the surface of the bed not having been cleaned for three months, which will probably not occur again.

While the improvement of the water by the removal of the suspended matter and the burning up of the organic matter that was readily oxidizable was very satisfactory, the most important change and the real object of the construction of the filter was the removal of bacteria, and especially of those kinds of bacteria that are dangerous to health, known as disease germs.

The removal of bacteria is not merely a straining process; it is accomplished by making conditions unfavorable to the life of bacteria in the passage through the filter, which conditions grow with the proper use of the filter. In the first three days 75 per cent. of the number of bacteria applied came through the filter. In the next three days 30 per cent. came through, but in the first week in October only 4 per cent. came through, and in the next week 2 per cent.; that is, during the first three weeks use the number of bacteria in the effluent rapidly decreased to 2 per cent. of the number applied, and from that time to the present, excepting on two occasions, when work on the filter or in the pump well interfered with the results, the effluent from the filter has contained 1.7 per cent. of the number of bacteria contained in the river water, the filter having removed 98.3 per cent. of all the bacteria in the water applied to it.

But the result given to the people is better than this. It appears that with the removal of those parts of the organic matter that are easily oxidized, the food material of the bacteria has been removed, and as the water flows on through the reservoir and through the pipes the conditions of life are still

unfavorable for the bacteria, and they go on decreasing so that the numbers found at the outlet of the reservoir are but 1.2 per cent. of the numbers in the river water; and at the tap in the City Hall the numbers of bacteria found are but nine-tenths of one per. cent. of the numbers in the river water. More than 99 per cent. of all of the bacteria of the river water have been removed.

The experiments of the State Board of Health go to show that with this result we can rely upon the complete extinction of all of the disease-producing germs that may have been in the water.

We have seen the effect of the filter upon the bacteria of the water applied to it; we will now seek the effect of the filter upon the inhabitants of Lawrence. It has been stated that the deaths from typhoid fever in Lawrence were about three times those of other cities in the State. Its relation to other cities from a broader field is shown by Diagram No. 1, in which are given the percentages of mortality from typhoid fever to the total mortality in London, New York, Boston, Philadelphia, Chicago and Lawrence.

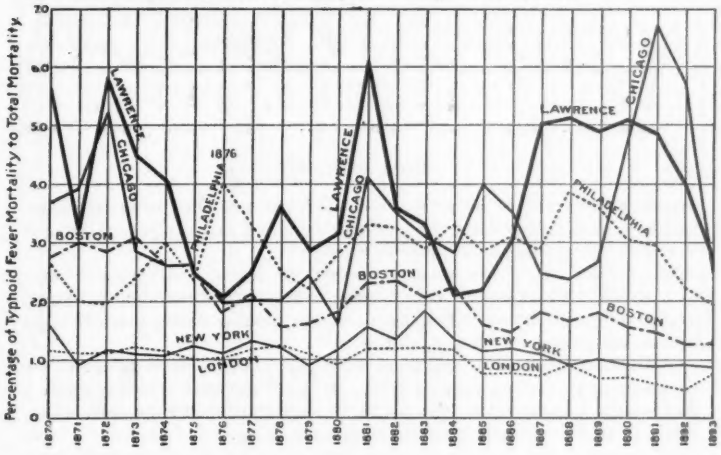



DIAGRAM NO. 1.

That the typhoid fever that has in the past affected Lawrence so seriously has come down the river, year after year, may be confirmed by Diagram No. 2, containing three broken lines. The heaviest line indicates the number of deaths from typhoid fever in 100,000 inhabitants in the city of Boston in each month in the past five years. This line represents approximately the number of deaths from this disease in 100,000 inhabitants in the cities of the State, and the months in which they occur. It will be seen that the months of greatest prevalence are September and October of each year. A vertical line has been drawn at such time of prevalence in each year at Boston, and this is nearly the time of its prevalence in our cities generally.

We see that in these months the disease prevailed to as great an extent in Lowell and Lawrence, but that following this period in about two months it prevails at Lowell to a much greater extent, and one or two months later it prevails to a still greater extent in Lawrence. This is the case year after year, until during the past winter when, in February and March, there was an in-

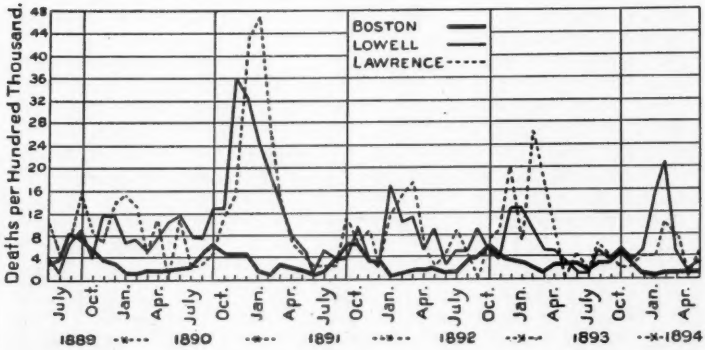



DIAGRAM No. 2.

crease in Lawrence following that at Lowell, but instead of being in greater numbers, as in former years, it was only to about half as many per 100,000, and the cause of this increase will now be considered.

In Diagram No. 3 the average number of deaths from typhoid fever at Lawrence for each month from October to May, in the preceding five years, are given by the heavy dotted line; and the number during the past eight months are given by the heavy full line.

The total number for the eight months in past years has been 43, and in the present year 17, making a saving of 26. Of the 17 who died, 9 were operatives in the mills, each of whom was known to have drunk unfiltered canal water, which is used in the factories at the sinks for washing.

The finer full line shows the number of those who died month after month, who are not known to have used the poisoned canal water. The whole number in the eight months is 8.

It is evident from the previous diagram that the numbers above the fine full line, here, follow after those at Lowell in the usual time, and were undoubtedly caused by the sickness at Lowell; but we have satisfactory reason to conclude that the disease was not propagated through the filter, but that the germs were conveyed directly into the canals and to those who drank of the unfiltered canal water. Among the operatives of one of the large corporations not using the canal water there was not a case of typhoid fever during this period. Warnings have been placed in the mills where canal water is used to prevent operatives from drinking it.

We find, then, that the mortality from typhoid fever has, during the use of the filter, been reduced to 40 per cent. of the former mortality, and that the cases forming nearly one-half of this 40 per cent. were undoubtedly due to the continued use of unfiltered river water drawn from the canals.

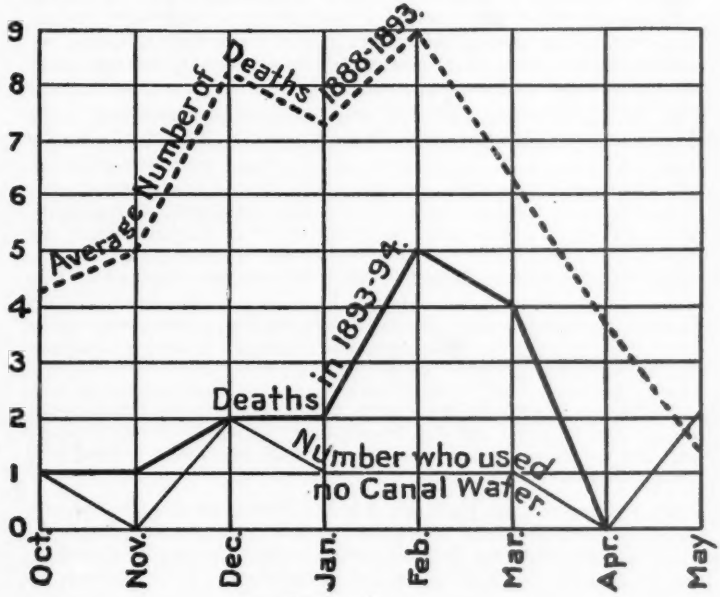



DIAGRAM No. 3.

The effect of the filter in preventing the communication of diarrheal and other diseases carried by water can be given after the season of the year when these diseases prevail. We can say further, at present, that the physicians have very generally reported a marked improvement in the health of the people since the filter came into use.

The study of this problem and its solution have established with more of certainty than ever before three important points in sanitary science.

1. The insufficiency of the self-purification of streams.

2. The ready conveyance of typhoid fever down a stream by sewage-polluted drinking water.

3. The practicability of protecting a community against an infected drinking water supply by natural sand filtration.

DISCUSSION.

MR. WINSLOW. I would like to ask Mr. Mills how far these typhoid fever germs can be carried through sand, from which the water is not drawn so as to expose it to the air, and live?

MR. MILLS. We do not know how far. The communication of typhoid fever by water from polluted wells indicates that they may be carried a considerable distance, but we have made no definite experiments that will enable us to answer that question.

MR. WINSLOW. The reason I speak of it is on account of the location of our filter gallery in Waltham. It is some 700 feet across the river from our filter gallery to a place called Crescent Park, which is being built upon quite rapidly, and some 300 feet from the bank of the river we have put in a driven well to determine how much we lowered the water at this place when pumping down some 28 feet below the river, and we found that we lowered the well some two feet and a half. The bottom of the well is very fine sand, and the bottom of the well we dug is also fine sand. They are building houses on the park side and using cesspools, and finding that we lower the water there, has made it a question in my mind whether typhoid fever germs or other germs could get across the river to damage us, and I didn't know but you could give us some information.

MR. MILLS. We haven't any definite information on this subject, but I should think it would certainly be advisable to pump the sewage from the park into the Metropolitan Sewer and send it away, rather than to leave it in cesspools there.

MR. FITZGERALD. Mr. President: I wish to express the admiration which I think we all must feel, that here at last we have practically carried out on a large scale, and producing the most beneficent effects, the results of extended experiments that Mr. Mills described to us a few years ago in an address before this Association. It seems to me that the man who saves the lives of a community by scientific work of this kind, is more to be commended than a general of an army, who goes into the field and kills a lot of people. Yet the latter is covered with medals, while the former must take his recompense from inward satisfaction in the sense of the good work he feels he has accomplished. What we have seen from the profiles Mr. Mills has exhibited to us, showing the reduction of the typhoid fever death rate in Lawrence, seems to be almost a perfect proof of the success of filtration scientifically carried out. It seems to me this is simply the great forerunner of hundreds of filters which, in a few years, will be built throughout the country for the protection of the health of the citizens of our towns and cities.

There is one question I should like to ask Mr. Mills in connection with this subject, and that is in regard to the two kinds of sand, the 70,000,000 and the 50,000,000 sands. I have found in my experience that with water containing a considerable amount of vegetable matter, there is a deposit on the finer sand even down at the bottom of the tank. I have had tanks constructed

with finer sand at the bottom and coarser sand on top, and after two or three years' use, I have found a deposit on the finer sand underlying the coarser sand.

MR. MILLS. Such a layer will generally form under such circumstances. But you will understand that at Lawrence the two kinds of sand are not put one above the other. One occupies a width of 10 feet, and the other 20 feet by the side of that, and there is the same kind of sand from top to bottom. The 50,000,000 sand occupies the 10 feet immediately over the underdrains, and the next 20 feet over to the next underdrain is formed of the coarser sand, but it is all the same kind from top to bottom, so that there is no fine layer beneath to catch any organic matter which might go into the filter and be deposited there.

MR. FITZGERALD. Isn't there a lateral movement of the water through the coarser into the finer sand?

MR. MILLS. Yes sir.

MR. FITZGERALD. You think there is no danger of organic matter collecting under these conditions?

MR. MILLS. Very slight, I think, in that case. You will notice, the coarse sand of the underdrain extended for a width of 20 feet, and then the smaller stones extended to a width of 17 feet of the 30, so that is way beyond the limit of the finer sand, which was only 10 feet. Placed as that is, I think there is very little likelihood of there being any gathering of a layer of organic matter.

## REMARKS CONCERNING A RECENT PAPER ON THE FLOW OF WATER IN A COMPOUND PIPE.

BY

GEORGE A. ELLIS, Civil Engineer, Springfield, Mass.

[Read June 14, 1894.]

In the last Journal of our Association,* there is a paper by Mr. L. M. Hastings, C. E., entitled, "Some Measurements of the Flow of Water in a 36" and 30" Compound Pipe." Read March 14th, 1894.

This paper, taken in connection with its subsequent discussion as reported, seems to say that the pipe in question acts like a "Sealed pipe," and that Mr. Hastings' figures of the flow as determined by formula rather than observation, are based upon such a condition. The answers given to Mr. Coffin during the discussion, give emphasis to this supposition; but as it is contrary to the facts as noted and inconsistent with the figures given, there is somewhere an error that should be corrected.

This correction may be briefly stated as follows:

From what is known of the difficulty of maintaining a vacuum, we know that this pipe *cannot* act as a sealed pipe.

From the volume of the discharge and from the action of the water column, we know that it *does not* act as a sealed pipe.

From the volume of the discharge and from the action of the water column, we know that it *does* act like a pipe with the water column broken at or near the 2,500 feet summit.

First: This pipe cannot act as a sealed pipe.

Trautwine, 25th M. says, page 241, that a siphon can be employed in practice not exceeding 28 feet, "In such a case an escape must be provided at the summit—for the discharge of free air, which will inevitably enter, and soon stop the flow, unless this precaution is taken." That is, the air must be kept constantly pumped out, if a height of vacuum equal to 28 feet of water, or 24.76 inches of mercury is to be maintained.

This is a fact familiar to all accustomed to pumping from long lines of suction mains having any considerable rise above the hydraulic grade at intermediate points; the difficulties encountered at Kansas City, being perhaps as notorious as any, though the rise there, is much less than in this case.

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*Vol. VIII., page 189.

The difficulty of maintaining even a low pressure of vacuum in the presence of water from which the free air has not been expelled by boiling, has been proven too many times to require further proof now.

The fact that there is in this case a sufficient head to maintain a constant flow, does not alter the situation, as the entire column below the 2,500 foot summit is only prevented from following the laws of gravity and moving away from the upper column, by frictional resistance and atmospheric pressure; so that to preserve the continuity of the column 28 feet of water must be constantly sustained by the atmosphere alone; as soon as the column breaks, the lower portion will settle in the pipe as fast as the air accumulates, till the presence of ordinary atmospheric pressure at the summit, the water would pour over the summit and run down the pipe as in a gutter, to a point where the velocity and frictional head would be with open gate, sufficient for the discharge, which in this case would not exceed 0.25 feet above Fresh Pond, leaving a break under such conditions of 33 feet.

The elder Trautwine, in the 8th M. page 537, for pipe with a profile like the one under discussion, ignores the possibility of siphonic action, and distinctly says, "The pipe must now be regarded as divided into two sections—each having its own grade line."

Second: This pipe does not act as a sealed pipe.

If it did, its discharge should be that due to a head of 64 feet, which after allowing for compounding according to Howard Murphy's formula as given in Trautwine, 25th M., as applied by Mr. Hastings, would be approximately determined by well known formulæ, as follows.

According to that of Darcy, for new and strictly straight pipe lines, it would be about 11,592,000 per 24 hours.

By tables from Weisbach's formula, Trautwine, 25th M., page 251, about 10,886,000 gallons.

By "Ellis' tables," about 10,915,000 gallons.

By Kutter, as given in Trautwine, 25th M., page 244, with "n" equal 0.12, and "c" equal 117, about 12,240,000 gallons.

The observed discharge of 8,066,800 gallons, shows a variation so great as to prove this head impossible.

The action of the water column is equally conclusive, as there would be no more disturbance in the column from opening and closing the discharge gate, if this pipe acted as a sealed pipe, than there would be in a pipe, the summit of which did not rise above the hydraulic grade line; that is, with proper care in the manipulation of the gate, no considerable disturbance of the column would be observed, except a change in the volume of the flow as the gate was being opened or closed; although as the frictional resistance increases so much faster than the volume, the apparent effect of moving the gate either way, when nearly open, would be very slight.

Third: This pipe does act like a pipe with the water column broken at or near the 2,500 foot summit.

As its discharge is practically that due to the head at that point.

By the formulæ before employed, the discharge at this summit should be: By Darcy, 8,316,000 gallons per 24 hours; Weisbach. 7,632,000; Ellis' tables, 7,740,000; Kutter, 8,794,000 While the observed flow was 8,066,800, or between the figures from Darcy and those of Ellis' tables. These figures agree so well with the theoretical discharges given by Mr. Hastings, as to make it seem doubtful if he is correctly reported in the discussion.

Trautwine, 8th M., page 538 and note, foot of 543, quotes practical formulæ giving from 10 to 13 per cent. less flow than does that of Darcy, or less than any of the figures named above.

As Kutter's formula is difficult of application on account of the uncertainty attending the selection of the proper coefficient for roughness, and as Darcy's formula is based upon perfect conditions, which are impossible in practice, it must be conceded that the observed flow was as large as could be expected, in fact so large as to speak well for the care with which the pipe was laid.

It is proper also to note, that without the application of vacuum gauges to the lower two summits to determine if any degree of rarification of the air is maintained in the space of the broken water column, and if so, proper allowance made therefor; or if no such rarification exists, then that the depth of water flowing over the summit be ascertained, so that the effective head at the summit becomes a known quantity; the observed flow cannot be compared with the figures of any formula, with exact accuracy.

The disturbance of the water column was that of a column broken by air; whenever, during the process of opening the gate, the height of the column supported by the atmosphere became such that the air commenced to separate from the water, violent surging of the column consequent on these sudden changes would result, alternately compressing the released air, then allowing its expansion and increased amount, till an equilibrium was finally established at or near normal atmospheric pressure. In closing the gate, the compression of the air, its elasticity, and its forced absorption by the water, would cause a similar commotion; but till the gate had been closed sufficiently, so that the head of water within the pipe required to discharge the maximum volume through the pipe below, and past the gate, had risen so as to cause sensible compression of the imprisoned air, the disturbance would not commence.

All of which corresponds with the observed action of the gate and water column.

It may be added as a deduction to be drawn from the foregoing, and as nearly as can be estimated from the published profile, that if for the 800 feet of this pipe next to the outlet, or that portion below the last summit, a 16-inch pipe and gate had been substituted for the 30-inch, no decrease in the maximum flow would have been occasioned, and the disturbance consequent on opening and closing the gate would have been materially reduced, if not eliminated.

## DISCUSSION.

L. M. HASTINGS. In the above paper by Mr. Ellis three propositions are laid down with dogmatic positiveness of statement, and they are attempted to be proved by certain quotations, figures and opinions. Let us examine these a moment.

First—"This pipe cannot act as a sealed pipe." To prove this, an extract is given from Trautwine's hand book. In the section from which this quotation is taken reference is clearly made to a syphon having both ends below the high point or apex; which is not the case with the syphon under consideration. The highest point in that part of the line which would act thus, is still 28.5 feet below the level of the source, and so could act as a syphon only when the pipe was free and the flow at least comparatively unobstructed. The moment any obstruction should occur, as the partial closing of a gate, accumulation of air, etc., the pipe would act under pressure until the obstruction was removed. I cannot agree with Mr. Ellis that this fact "does not alter the situation" but hold that any considerable accumulation of air at the summit would be driven down the pipe with the water by the head due to the decreased water way in the pipe. The end of the pipe at Fresh Pond is in the form of an inverted syphon so that it is really a water sealed pipe. Now I cannot believe that this column of water, from the summit to the end at Fresh Pond, sealed as it is against the entrance of air at its mouth, exerts no force or pull upon the column behind it, but simply as Mr. Ellis states "runs down the pipe as in a gutter!"

I have not the ancient edition of Trautwine (8th M.) from which the second quotation is made, but if the quotation is correct and the reference is to a pipe with a similar profile to the one now being discussed, Mr. Trautwine has since seen the fallacy of that statement and corrected it, for in the 22 M. on page 240, a diagram of a pipe line exactly analagous to this one is given, and after stating the conditions, which are exactly similar to those obtained here, he says in bold faced type that under these conditions "*the pipe becomes a syphon.*" The same view is taken by J. T. Fanning in his book, page 231. I am still inclined to think that the pipe CAN act as a sealed pipe.

In support of the second proposition that "the pipe does not act as a sealed pipe" certain figures are presented purporting to show the discharge which might be expected if the full head of 64 feet were considered as efficient in this case, but as the figures are based on a coefficient for "new and strictly straight pipe," they have not the slightest value, as the pipe is neither new, straight, nor clean, as an examination of the alinement and the pipe itself, on enquiry from those familiar with the facts, would reveal. That the condition of the pipe has a great influence on its discharge is a fact which "needs no further proof now" but which seems to have been temporarily forgotten or ignored by the computor of the quantities given. I believe that the use of Darcy's coefficient for rough pipe given by Mr. Gould in his book referred to previously by me, or the formula of Professor Unwin for incrusted pipes given

in the Enc. Brit. Vol. 12, page 480, or one of Fanning's coefficients for rough pipe given on page 269 of his book, will give results more nearly consonant with the conditions as they exist.

The quantities obtained by using the low head of 28.50 feet which I understand Mr. Ellis claims to be the correct head to be used, would then be much smaller than the observed flow, which is not what would be expected, as there would probably be some obstruction due to air at the summit and the observed flow would naturally be somewhat less than the computed flow.

But further, if the water column is broken at the summit, and the lower part acts as a gutter, with a free end, not as a syphon, there would be found at the summit a slight pressure of water or else free air.

If on the other hand the column is not broken, but acts as a syphon, then there would be, as Trautwine says in the article referred to (22 M., page 240) a "negative pressure or tendency to vacuum" causing a sucking in of air if an opening is made in the pipe.

Now this latter condition is *just what is found to exist by experiment on the pipe itself.* On opening the air valve at the summit, air is sucked into the pipe with great force!

It seems to me that no better demonstration is needed of the fact that the pipe DOES act as a sealed pipe.

The explanation of the action of the water column on opening or closing the gate is largely a matter of opinion. In my opinion it is evidence that the pipe does act as a syphon. The column rising so near the vacuum line, the starting or stopping of the column on either side of the summit before the inertia of the other column can be overcome and the uniform flow obtained, produces a tendency to vacuum and its recovery at the summit, causing a surging of the water in the pipe, much like the dancing of a weight suspended by a rubber string.

If the first two propositions are not true the third one cannot be!

## OBITUARY.

HIRAM NEVONS.—Seventh president of this Association. Died at Cambridge, Mass., May 27th, 1894, aged 58 years.

Mr. Nevons was born at New Gloucester, Maine. In early life he was a ship carpenter. At the breaking out of the war he enlisted in Co. G, 25th Maine Volunteers. Returning from his military service, he took up his residence in Cambridge, Mass. He was appointed Superintendent of the Cambridge Water Works on May 8th, 1877, and ably performed its duties from that time up to the beginning of his last illness, a period of seventeen years. He rendered valuable service in the development of the Cambridge system of water supply, and his work was greatly appreciated by his fellow-citizens, with whom he was very popular. He possessed unusual executive ability, and the condition of the department shows how faithfully he labored for the interests of the city.

When the first suggestion was made for the formation of this Association, Mr. Nevons enthusiastically identified himself with the movement.

With two others he was appointed a committee to draft a Constitution and By-Laws for this Association, at a preliminary meeting held April 29th, 1882.

The result of the work of this committee was presented at a meeting held June 21st, 1882, on which day the Association was organized.

The same day he was elected one of the vice-presidents, and served for one year.

He was elected president for the year ending June, 1889, and filled the position most acceptably to the members of the Association.

On retiring from the position of president, he was elected treasurer, which office he continued to fill until the day of his death.

He was one of a committee of three to present a paper read at Worcester, June 21st, 1883, upon the "Causes and Prevention of the Waste of Water." He also presented a paper, read March 12th, 1890, entitled "Experience With a Thirty-Inch Gate."

By his death there now occurs the first break in the ranks of the twelve past presidents of this Association.

It is fitting to close this brief record of our beloved friend who has left us, with the following extract from the action taken by the Cambridge Board of Aldermen, on May 29th, 1894:

"By those who best knew him on the social side, as an associate and friend, Hiram Nevons was most beloved and honored. Tender and sympathetic in all the relations of life, strong in his personal attachments, honest as the day in all his actions, his cheery and welcome presence will long be missed and mourned in the daily walks where he was wont to be met. He needs no memorial stone to remind us of the form that has gone out from among us: the result of his life work will remain in our midst, and to his memory these will constitute a monument more enduring than brass." R. C. P. C.

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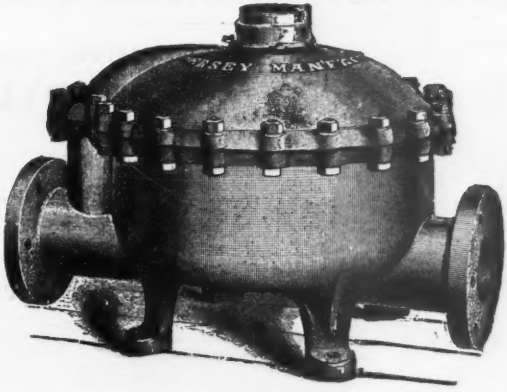


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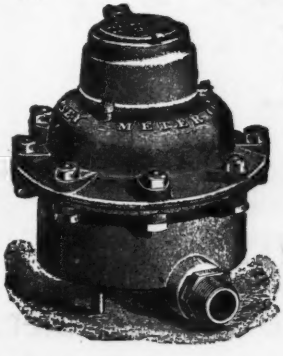


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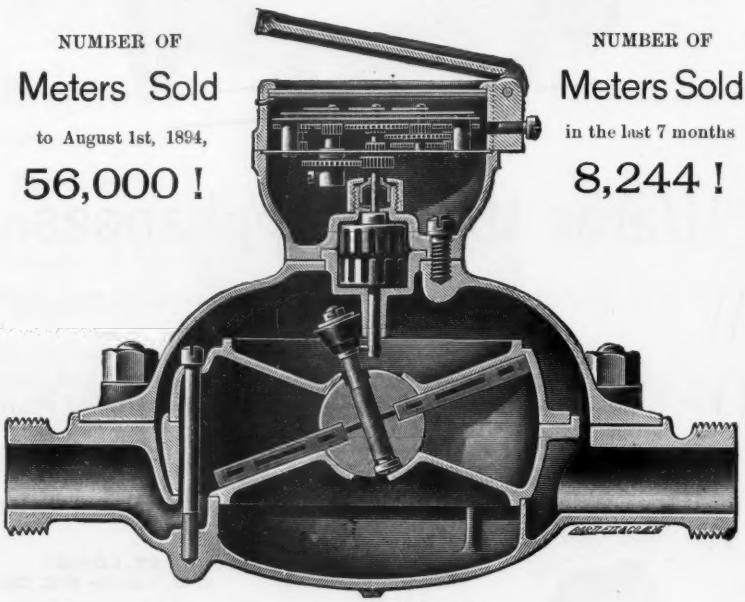

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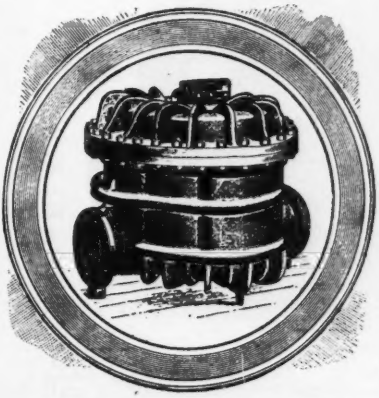

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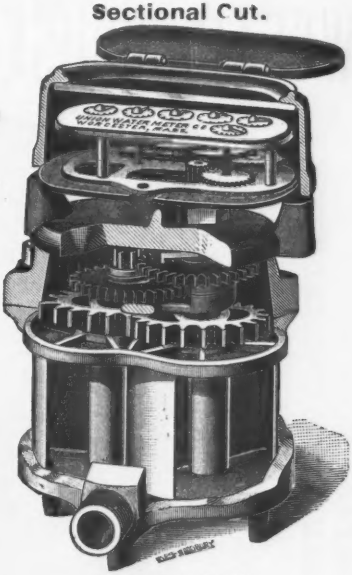

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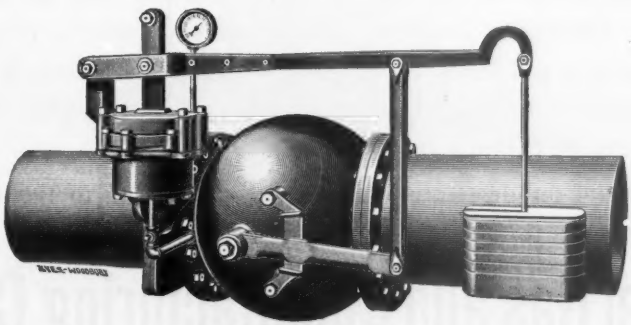

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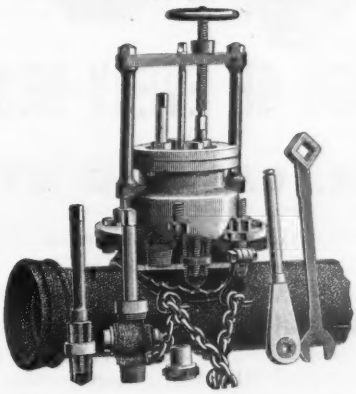

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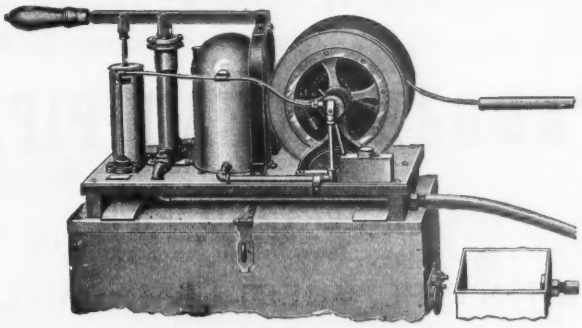

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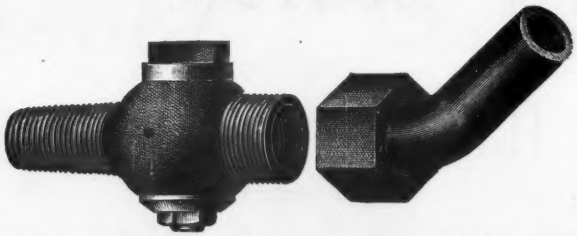

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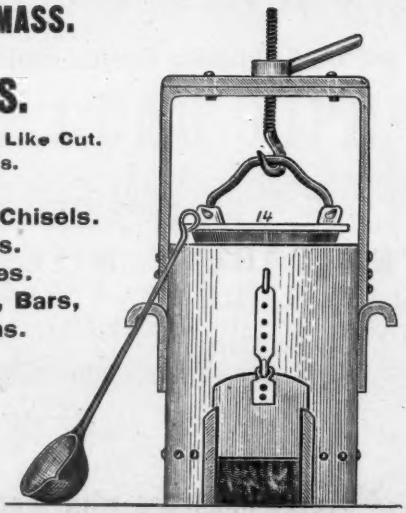


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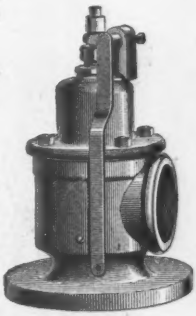

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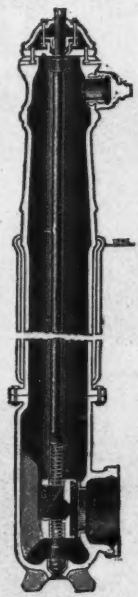

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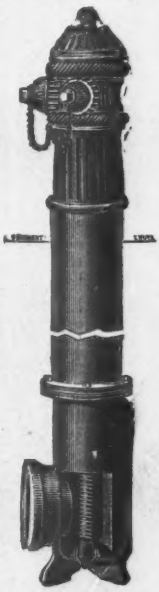

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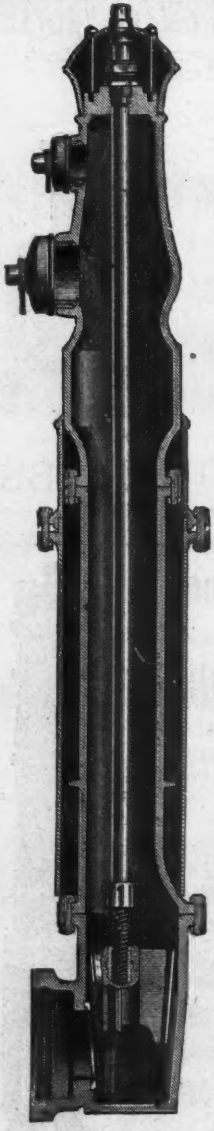

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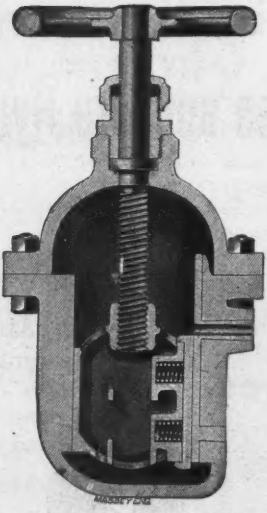
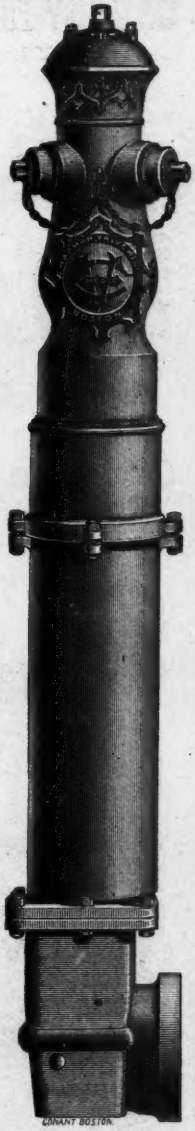


Section Drip Valve.



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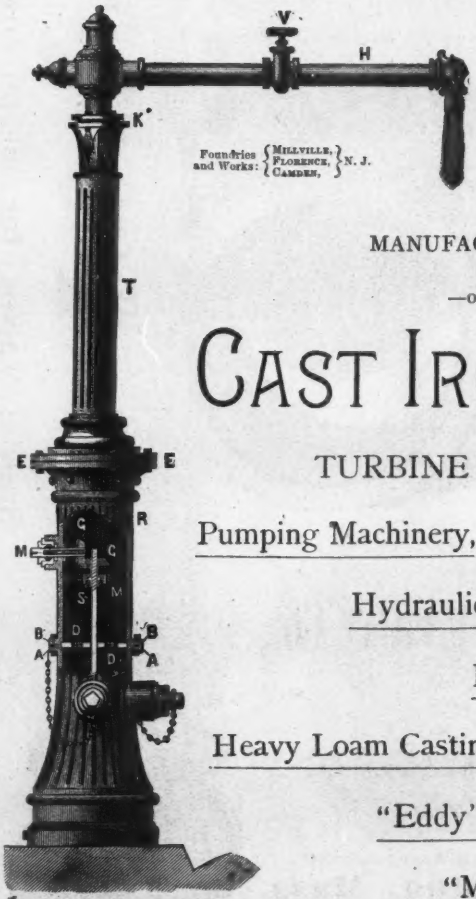


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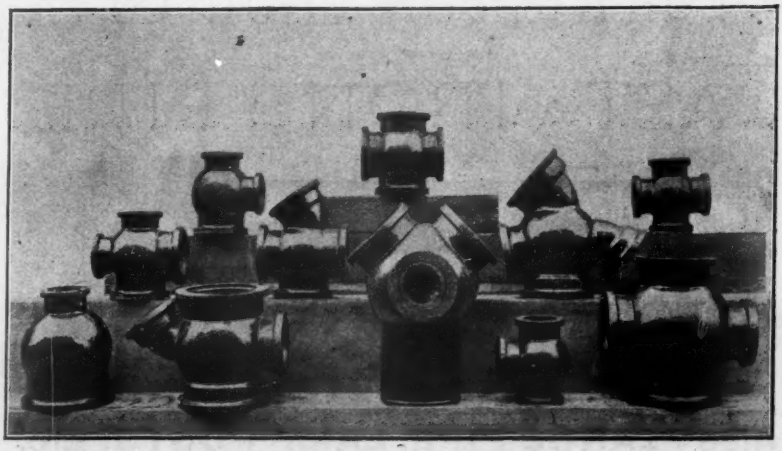

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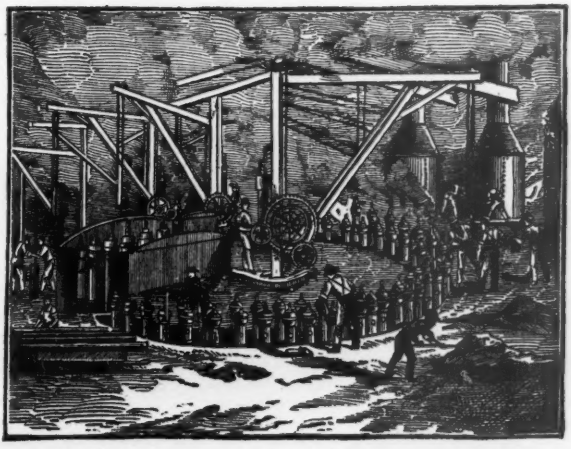

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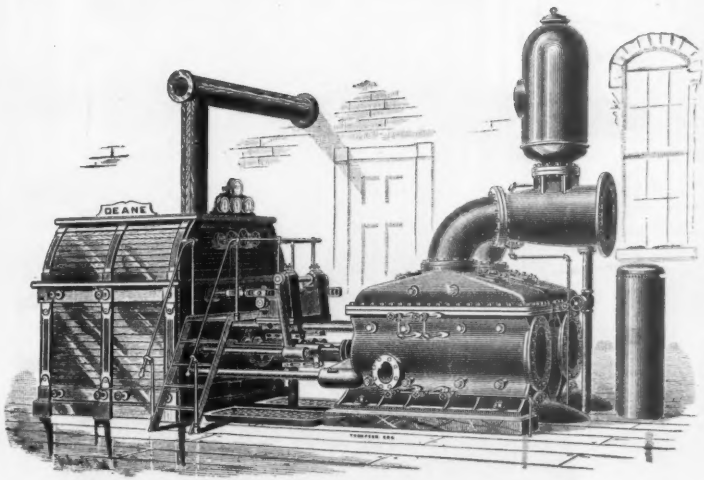


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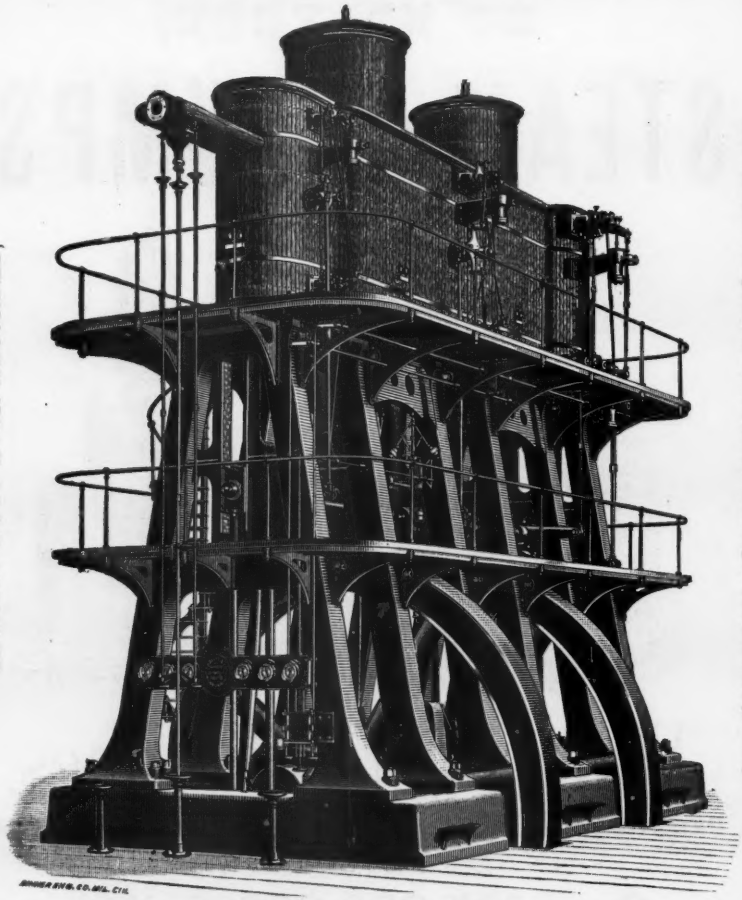

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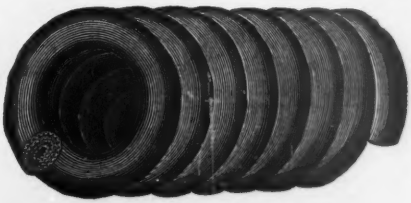

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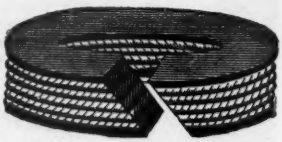

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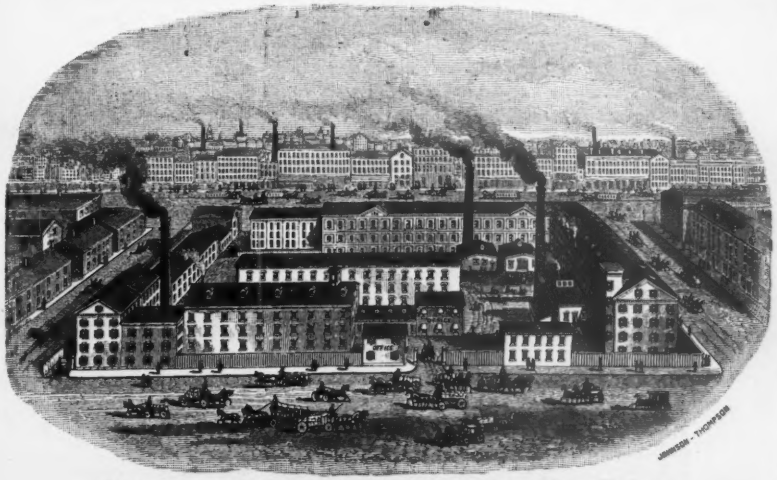

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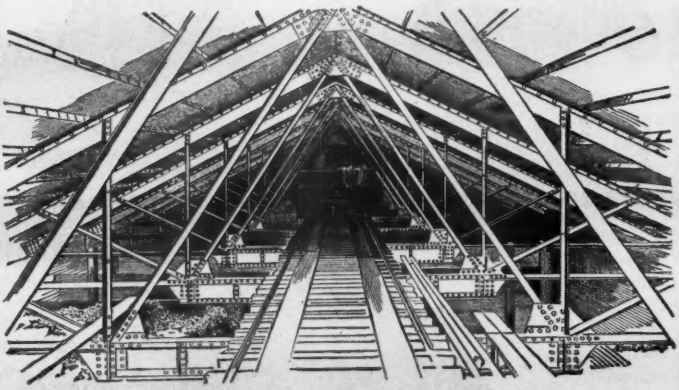

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